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The quaternary gravel deposits in the Lower Bristol Avon

THE QUATERNARY GRAVEL DEPOSITS OF THE LOWER BRISTOL AVON

by

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THESIS SUBMITTED FOR THE DEGREE OF DOCTOR OF PHILOSOPHY AT THE UNIVERSITY OF BRISTOL.

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MEMORANDUM

This thesis presents the thoughts and results of independent research carried out in the Department of Geology at the University of Bristol under the supervision of Dr. A.B. Hawkins, between 1980 and 1985. The research has been funded by the Department of Education for Northern Ireland. All other published and unpublished material is fully acknowledged in the text.

Kay Borland.

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The work was undertaken in the Department of Geology of the University of Bristol, under the supervision of Dr. A.B. Hawkins, whose lively lectures and fieldtrips during my years as an undergraduate sparked off my initial interest in the Quaternary of the area. I would like to thank him for his continued help, criticism and encouragement.

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Mr. Butler of Gatcombe Farm, Long Ashton;
The Parks Dept. of Bath City Council (especially Mr. C. Richards).

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This thesis was deciphered and typed by Mrs. Sue Cottrell.

Finally, I am grateful to Rob for all his support, surveying services, and various vehicles, and to my mother for encouragement and help with the production of this thesis.

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ABSTRACT

Selected Quaternary deposits of the Lower Bristol Avon are described.

The literature on the gravels from Bathampton to Avonmouth supports a height related sequence including mammalian remains around Bath. Only a few of the findspots and containing deposits were recorded in sufficient detail; and similarly, apart from those at Chapel Pill, Lower Palaeolithic artefacts are poorly described. The tools have been considered as Mid-Acheulian (late Hoxnian - early Wolstonian). They are recorded as mainly associated with fluvial terrace material, often at relatively high levels, and sometimes disturbed by periglacial solifluction. The recent evidence of glaciation obtained from temporary exposures in the area during the early 1970s has implied a reinterpretation of some of the valley gravels to be necessary.

The aim of the research was to make detailed recordings of any terrace-like material, to undertake determinative sedimentary analysis, and to correlate the particle size and sorting of the various samples in relation to the field descriptions. Suggestions concerning their environments of deposition are made. The lithological content of the deposits was used to predict sources for the gravels, and a morphometric study of their component pebbles analysed the size, shape and lithological parallels between the deposits.

The study has resulted in a classification of the deposits into :

a) fluvial terrace gravels, from Bathampton to Keynsham, with associated fauna;

b) fluvioglacial deposits, found mainly at Sheepway and Portbury;

c) glaciogenic materials, e.g. at Chapel Pill, with associated artefacts.

The recorded provenances of the bones and artefacts have been related to the different materials, and their usefulness in further interpreting the deposits assessed.

A depositional history of the valley is proposed.

CHAPTER 1

THE STUDY AREA

Introduction :

This thesis records the study of the gravel deposits of the Bristol Avon valley, downstream of the Limpley Stoke Gorge.

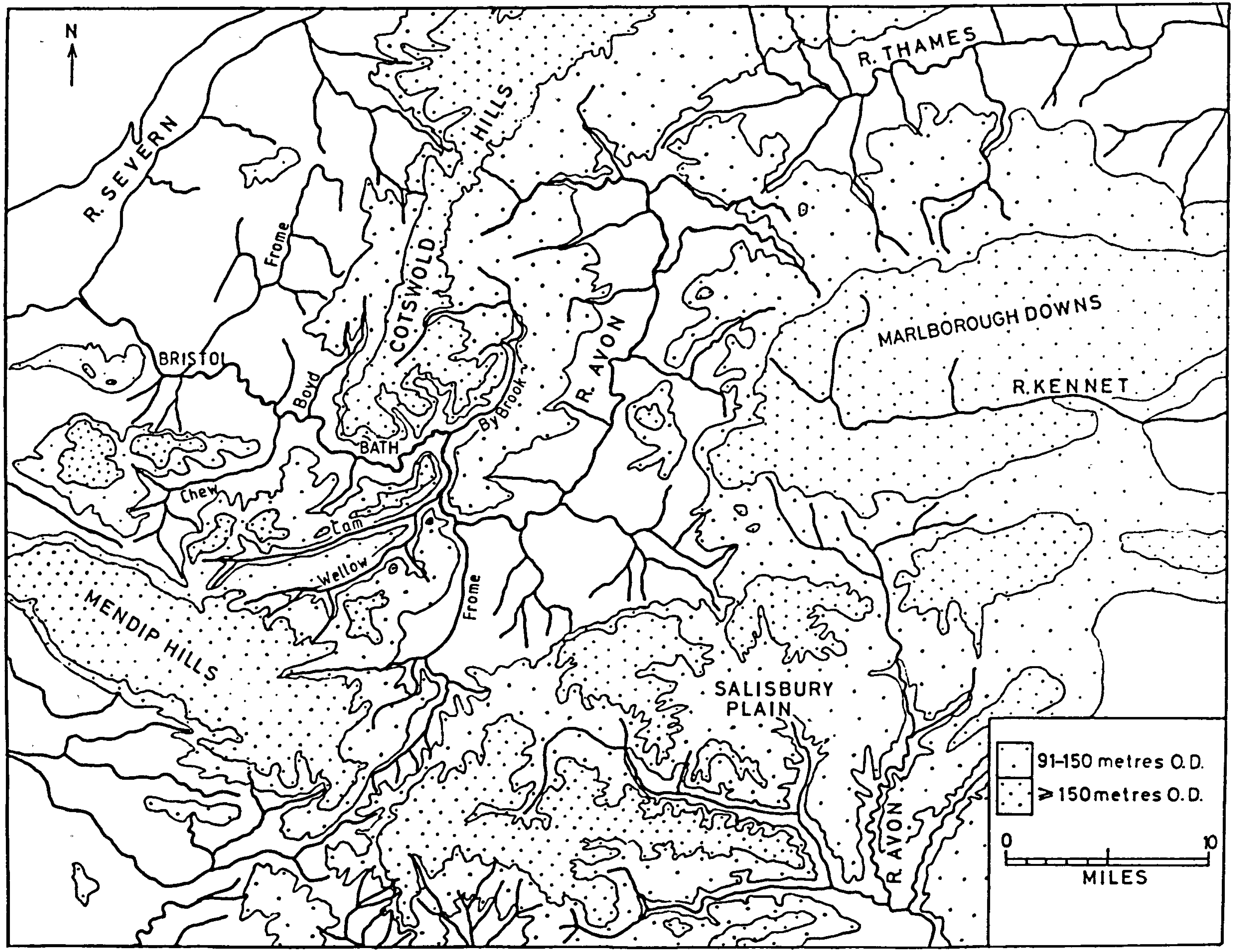
Previous work on the Quaternary Valley deposits consists of scattered reports of specific exposures and occasional reviews of the evidence, which classified the materials as a fluvial terrace sequence related to heights above sea level (Davies and Fry, 1929; Palmer, 1931).

The present research reviews the literature and describes new exposures of the gravel as examined during fieldwork between 1981-1985. The samples obtained were analysed in terms of their sedimentological parameters. The available data of the faunal remains and Lower Palaeolithic artefacts from the gravels has been studied.

The deposits have been reassessed in the light of this new information and the relation to the recent evidence of glaciation of the Avon-Somerset area. A detailed investigation of the nature and origins of the "terrace gravels" of the Bristol Avon valley should enable other workers to make a comparison with those of the Rivers Thames and Severn.

THE BRISTOL AVON :

The Avon rises in the Cotswold Hills, Eastern Mendips, and the Cretaceous uplands, and flows through an area of complex and varied geology around Bath and Bristol to the Severn Estuary at Avonmouth (Fig. 1.1). At present the River is predominantly mud carrying although the remains of gravel terraces found on either side of its course show that in the past it was a faster, possibly turbulent river capable of carrying material at least of cobble size.



<u>Figure 1.1</u> :
The catchment area
of the Bristol Avon

The total catchment area of the River Avon is 2217 square kms (856 square miles), of which approximately half lies downstream of the Limpley Stoke Gorge (figures from Wessex Water Authority). The main source is taken as the Crow Down Springs at Didmarton (ST 833869), although others are found at Badminton Park (ST 802840) and to the north of Tetbury (ST 905940).

The headstreams flow eastward with a consequent drainage pattern developed on the dip slope of the Cotswold Hills. At Great Somerford the headwaters have formed the River Avon which then turns southwest to flow through the Oxford Clay Vale. Downstream of Bradford-on-Avon its course turns through 150° and the river has eroded a steep-sided valley through the Great Oolite Series, before passing northward through the Mid-Jurassic succession in the Limpley Stoke Gorge. Downstream of Freshford the River flows northeasterly through a series of gorges cut in the resistant beds of the local geology (at Limpley Stoke, Conham and Clifton) and across intervening broad areas of floodplain (at Bathampton, Keynsham and Bristol).

Fig. 1.2(a) shows the gradient of the river from its source to the Severn Estuary, taken from data on the Ordnance Survey topographic maps. It decreases from an average of 1:5 between Malmesbury and Bradford-on-Avon, to 1:14 between Freshford and Avonmouth, i.e. downstream of the entrance to the Limpley Stoke Gorge. There is no obvious change in gradient as the river passes through the gorges, which is probably due in part to the surface level being related to the accreting alluvium.

The Avon Valley has a rather low rainfall of less than 800mm per annum, whereas its two major source areas of the Mendips and the Cotswold Hills receive around 1200mm and 900mm respectively. The comparatively high incidence of summer thunderstorms with associated high rainfalls can result in severe flooding however, e.g. on 10th July 1968, up to 170mm fell, peaking at a rate of 25mm per hour for 6 hours. The built-up catchment area of the southern tributaries, notably the Malago, contributed to the severe flooding experienced in the Bedminster district of Bristol.

Fig.1.2a GRADIENTS OF THE BRISTOL AVON

FLOW RATES OF R. AVON AT BATH Fig.1.2b

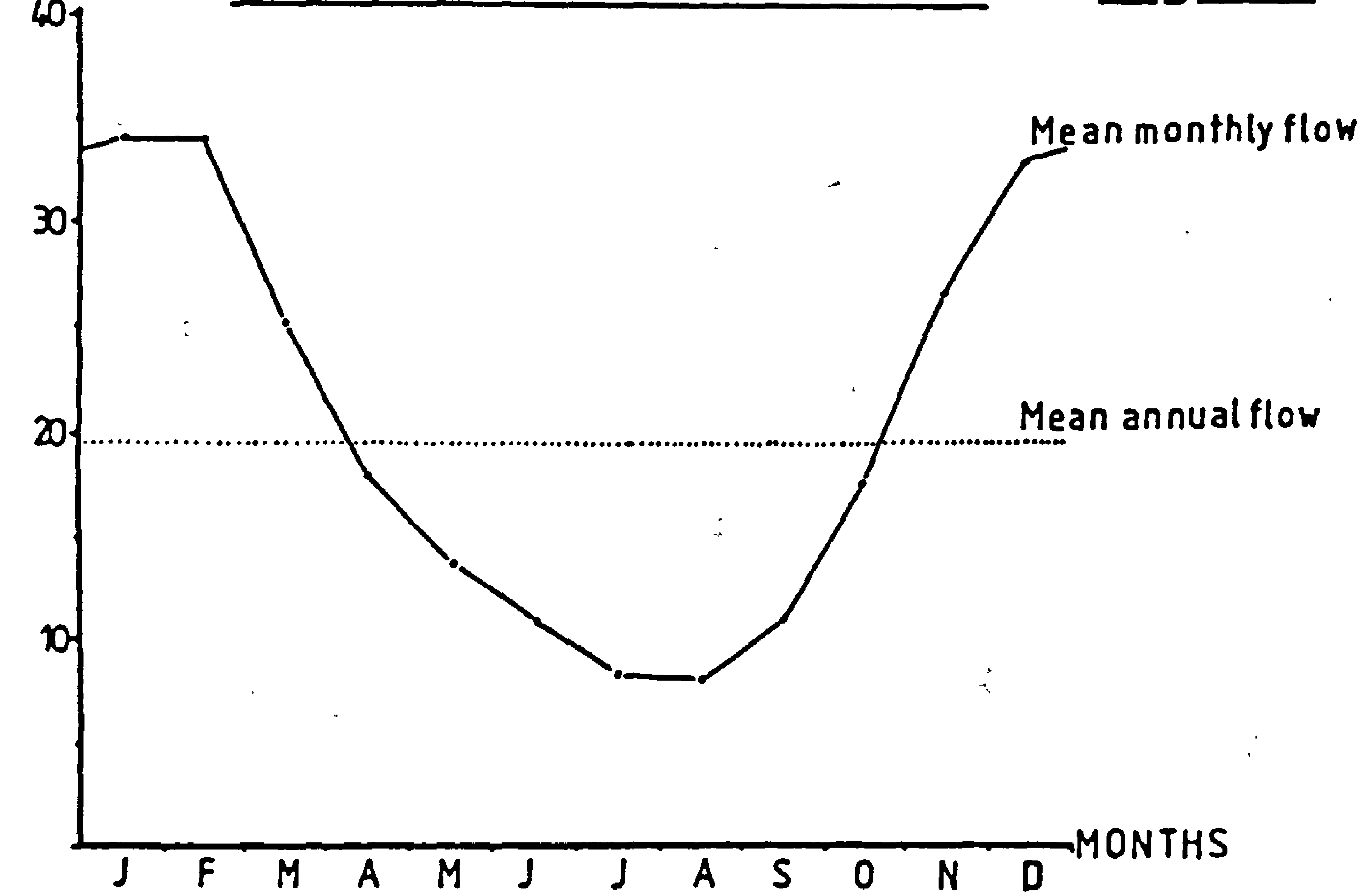
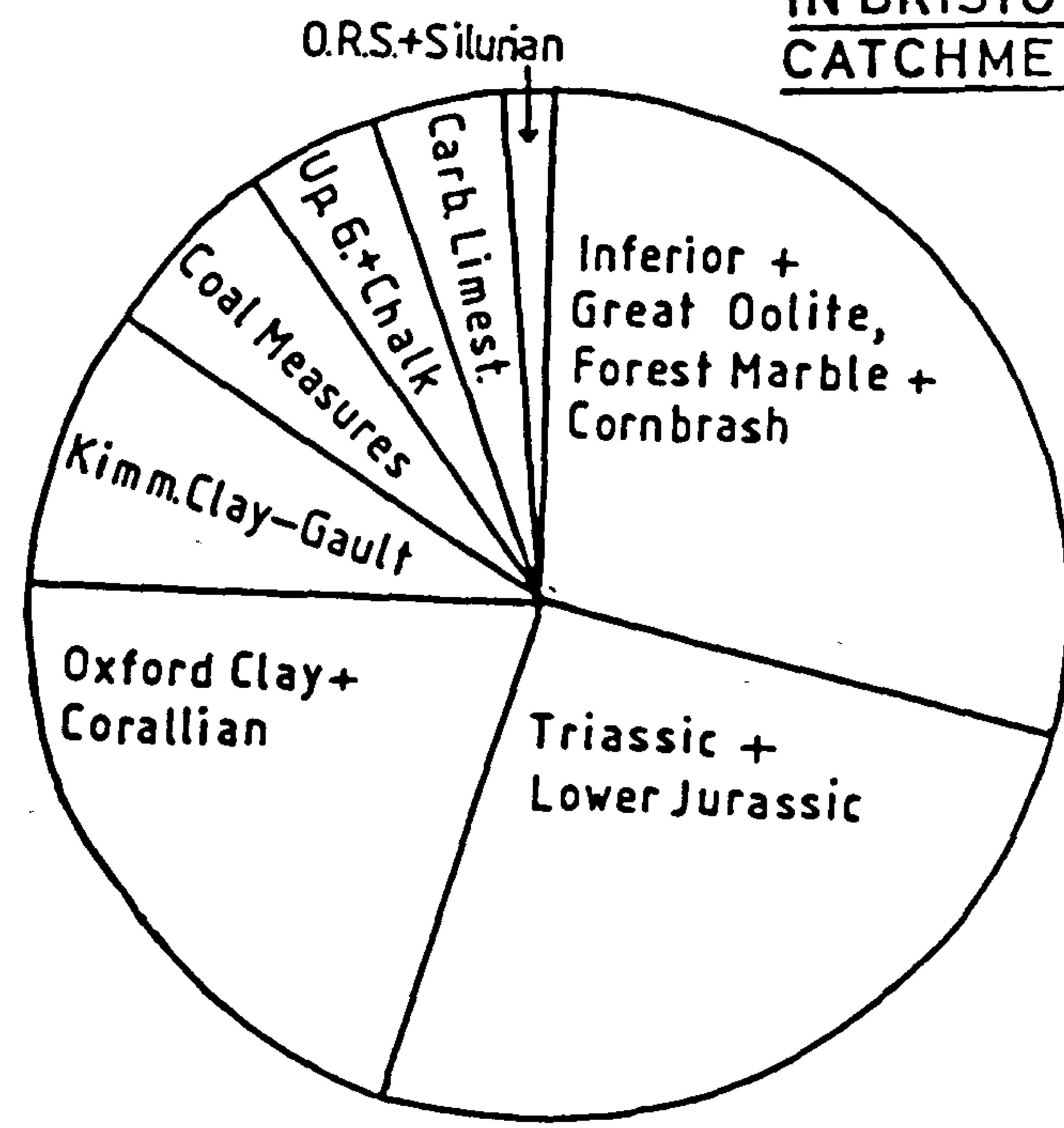


Fig.1.2c AREAS OF GEOLOGICAL OUTCROPS IN BRISTOL AVON CATCHMENT



Whilst river discharge in past climates may not be comparable with that of the present, the mean annual flow rate recorded by the Bristol Avon River Authority at Bath is 19.8 cumecs (Fig. 1.2(b)). The total flow from the catchment is 26.3 cumecs in normal circumstances (data from Brookes, 1974; Wessex Water Authority, pers. comm.).

RELIEF AND GEOLOGY :

Although extensive areas of fluvial terrace material exist upstream of Bradford-on-Avon (Geological Sheets 265, 266 and 252), the present study considered only those gravels downstream of the Limpley Stoke Gorge, i.e. between Bathampton and Avonmouth. In this downstream section the terraces remain as relicts in the more open valley between the gorge sections.

Fig. 1.3 shows the relief of the area and Fig. 1.4 the underlying geology, as recorded on several British Geological Survey 1:63360 sheets. In the southern end of the Cotswolds the predominant strike is NE-SW, as represented by the cuesta of Inferior and Great Oolite north of Bath, and the Triassic sandstone and Keuper Marl, north of Bristol. The Lower Bristol Avon flows to the northwest, i.e. normal to these Cotswold strata/ relief trends.

The areas of highest ground are formed by the Carboniferous Limestone of the Mendip Hills along the southern margin of the catchment, and the Jurassic cuestas around Bath. Several broad planation surfaces have been developed e.g. on the Broadfield Down Carboniferous Limestone at about 150m O.D.; the Failand Ridge at c. 110m O.D.; and over much of the Coal Measures NW of Bristol and the Lower Jurassic to the south of the city at c. 75m O.D. (Trueman, 1939; Wooldridge, 1961; and Fig. 1.3).

A detailed geological analysis was not the main aim of the present study. A general appreciation of the geology of the area is contained in the British Regional Geology handbook of the Bristol and Gloucester District (Kellaway and Welch, 1948). However, in order to differentiate the lithologies of the terrace gravels, it was important to acquire a knowledge of the characteristics of the main strata and their relevant outcrop proportions. Fig. 1.2(c) shows the percentage of each stratigraphic group over the area of the Bristol Avon catchment, which will be of interest

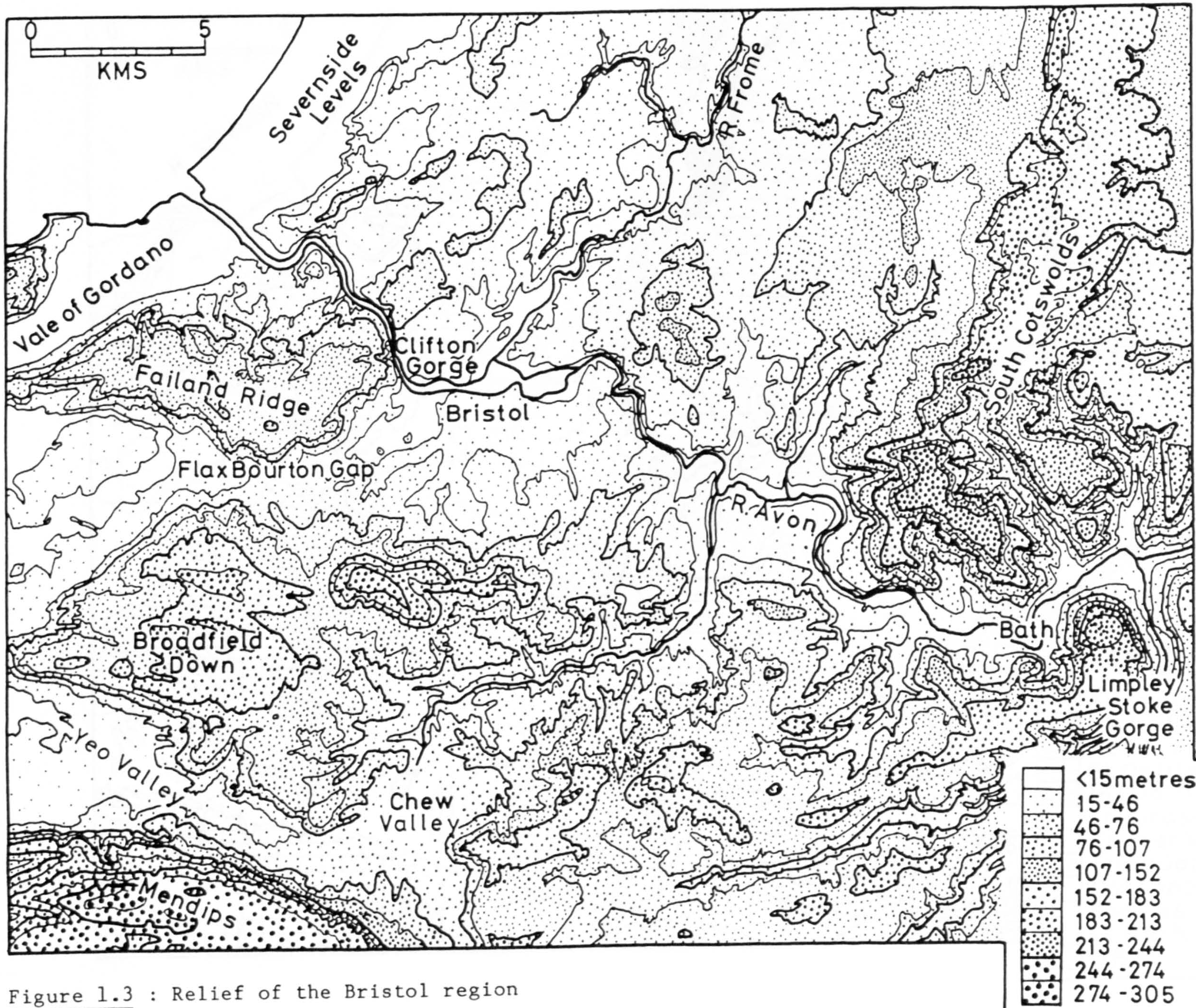


Figure 1.3 : Relief of the Bristol region

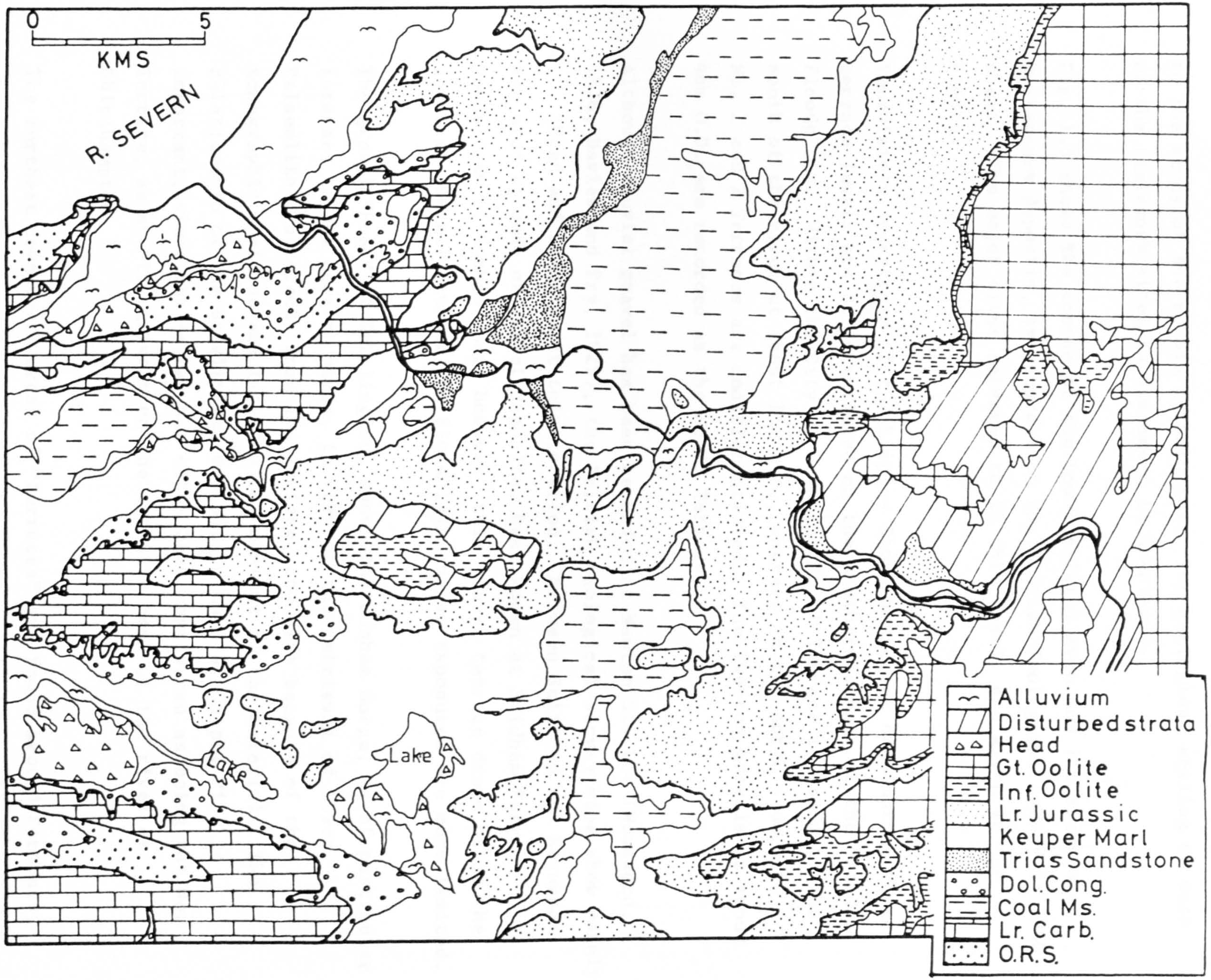


Figure 1.4 :
Geology of the
Bristol region

to the study of the pebble lithologies. The geological setting of each of the fieldwork sites is discussed in Chapter 4.

Fig. 1.5 shows the course of the Lower Bristol Avon and its associated Quaternary deposits, as recorded on the British Geological Survey 1:63360 sheet. The major sites referred to in this thesis are given in the Figure.

Immediately downstream of the Limpley Stoke Gorge, at Bathampton, three terrace levels are differentiated on the southern slopes of the broad floodplain. Within the City of Bath the No. 1 Terrace is found to the south of the river at about 15m O.D., whereas on the north side, the No. 1 and 2 Terraces are undifferentiated. The Twerton gravels at about 46m O.D. are recorded as the No. 3 Terrace.

Although fluvial gravel has been recorded at Newton St. Loe (Woodward, 1876; Davies and Fry, 1929), the British Geological Survey maps show mainly Head and alluvium at this location. Between Saltford and Keynsham are wide spreads of gravel deposits, best known at Stidham Farm. Downstream of Conham Gorge however, this gravel terrace drops below the level of the alluvium of the floodplain and so exposures are more limited.

The gravel "Head" at Brislington, above the Conham Gorge, is of particular interest to the present study, in view of the retrieval of Lower Palaeolithic artefacts from its surface, and also because of the topographic position and lithological content of the material. The relationship of the Brislington deposit to that at Chapel Pill is important, since the latter has often been considered as being the No. 2 Terrace, as are the gravels on the opposite bank of the river at Shirehampton.

The furthest downstream areas of "terraces" are found around Portbury, where there are several exposures above the level of the alluvium. In this region buried gravels are known from borings taken at the time the new docks scheme was being investigated.

The final area of interest is the Flax Bourton Valley, where a study of the gravel deposits has helped to elucidate both the origin of the watershed at 46m O.D., and the relation of this drainage system to that of the River Avon.

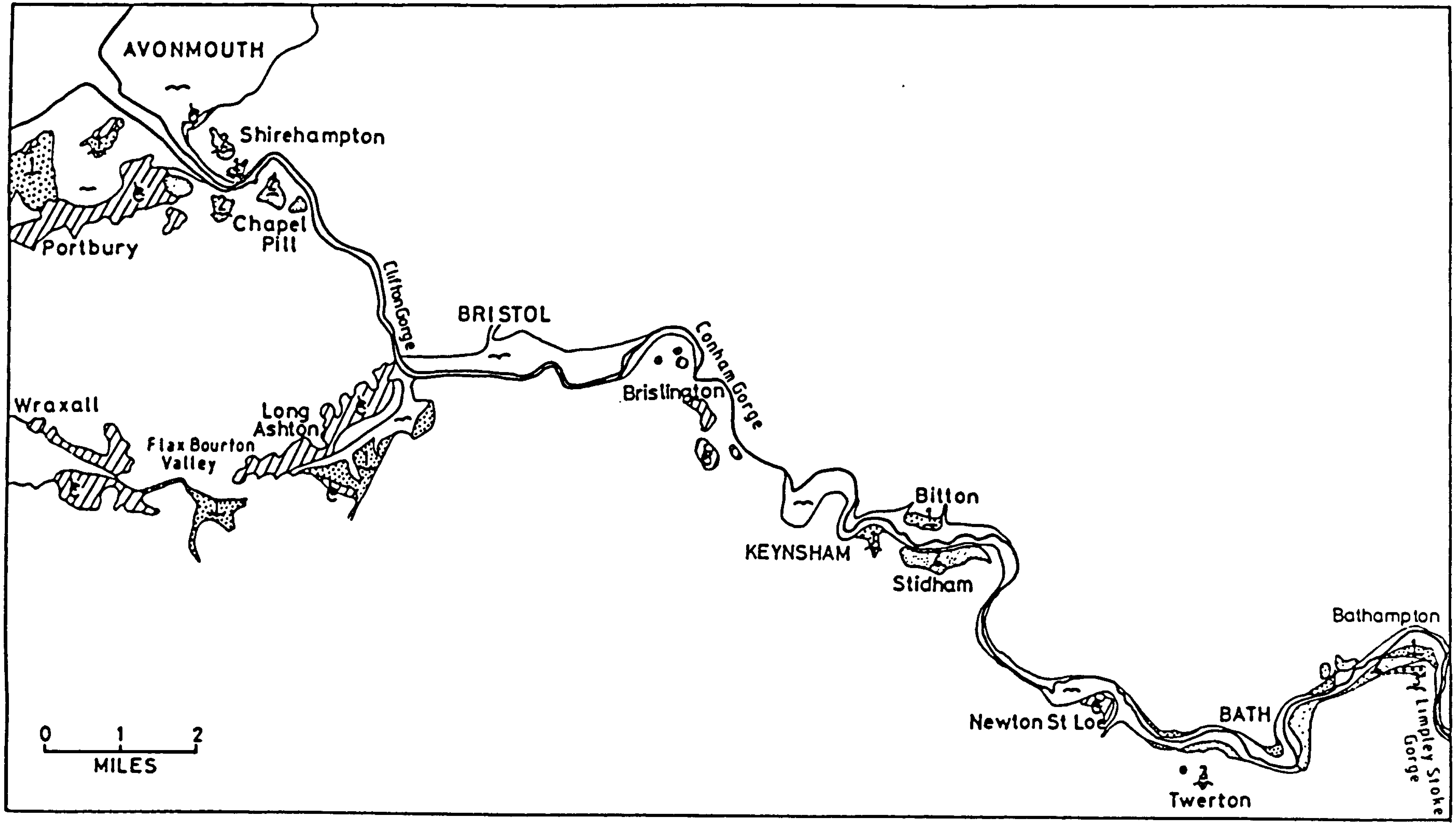


Figure 1.5 : The course of the Lower Bristol Avon and its associated Quaternary deposits

CHAPTER 2

PREVIOUS STUDIES OF THE BRISTOL AVON TERRACE GRAVELS

Studies of the Quaternary geology of the region have been based on the recording and interpretation of the drift deposits, and on the analysis of the geomorphological features. Much interest has focussed on the present and former courses of the Bristol Avon and its relation to the geological and geomorphological features of the area (Trueman, 1939; Bradshaw, 1966; Frey, 1975 etc.).

The extensive list of papers in Donovan's bibliography of the literature on the Quaternary of the area (1954 and 1964, updated in Hawkins and Tratman, 1977) reveals the wide variety of superficial deposits throughout Somerset and Avon. Unfortunately the nature of the exposures does not allow a clear stratigraphic relationship to be established between the different types of deposits. Exceptions to this are found at Brean Down (ApSimon, Donovan and Taylor, 1961), where a series of breccias and aeolian sands are believed to represent the transition period between the Pleistocene and the Post-Pleistocene, and secondly at Kenn (Gilbertson and Hawkins, 1978), where both glacial till and outwash gravels are cut by interglacial stream deposits.

THE AVON QUATERNARY DEPOSITS :

The superficial deposits fall into seven main environmental groups; a brief mention of each of these is made below to illustrate the position of the fluvial terrace gravels in the Pleistocene succession of the area. No attempt will be made in this thesis however to discuss the other groups of deposits in detail.

1) Cave and fissure deposits :

These are developed in the Carboniferous Limestone of the region, predominantly on Mendip, but also at other locations such as the Durdham Downs, and at Almondsbury. The oldest deposits known are from Westbury-sub-Mendip where examples of Early Acheulian palaeoliths were found associated with a Cromerian fauna (Bishop 1974, 1975).

The Durdham Down fissure above the Clifton Gorge at 91m O.D. contained a warm period fauna of Elephas antiquus, Hippopotamos, cave lion and hyena and may date to the Ipswichian (Curtis et al., 1955; Donovan, 1966).

Many authorities consider the main group of Mendip cave faunas to be of Devensian age. The Hyaena Den at Wookey Hole (Tratman et al., 1971), Picken's Hole, and the caves of the Western Mendips gave evidence of Hyaena, horse, mammoth, rhino, cave lion and Irish Giant Deer.

The Walton Bone Cave at Holly Lane, Clevedon (described by many authors,(see Palmer, 1934) was rich in fauna and was sealed by periglacial loams and breccias, now dated to the Devensian by Gilbertson and Hawkins (1974).

The fauna from Aveline's Hole, Burrington Combe, and Sun Hole and Gough's Cave, Cheddar, represent a later stage fauna, lacking in remains of mammoth, rhino and hyaena (Savage, 1969).

2) <u>High level "plateau" drifts</u> :

These occur predominantly on Bathampton and Kingsdown, Bath, at levels of 190 and 165m O.D. Until recently these were interpreted as examples of material from a former high level drainage system (Varney, 1924; Lacaille, 1954). Since the evidence of glaciation was found in 1969 it is possible now to explain these gravels, in a silty clay matrix, as glacial rather than remnant river deposits.

3) <u>Glacial deposits</u> :

Although the evidence of glaciation was noted from the presence of erratics by Trimmer (1854), and Harmer (1907) had suggested ice as the cause of the diversion of the River Avon through the Clifton Gorge, the widespread acceptance of the glacial theory has come only since 1969 with the study of more recent temporary exposures. The evidence is based on deposits mainly at Kenn (of glacial till and outwash gravels), and secondly within deep channels in the western end of the Failand Ridge e.g. Swiss Valley, Court Hill, and the Tickenham Valley (Hawkins and Kellaway, 1971; Gilbertson and Hawkins, 1978).

4) Periglacial and aeolian deposits :

The best known examples come from Brean Down (a series of angular limestone breccias and windblown sands (ApSimon et al., 1961) and Holly Lane, Clevedon (Gilbertson and Hawkins, 1974) where frost weathered breccias flank the Carboniferous Limestone. Less well known are the spreads of reddish loams or coversands material found for example over the Vale of Gordano, and at Clevedon (Greenly, 1922), Brean Down (ApSimon et al., 1961) and Kenn (Gilbertson and Hawkins, 1978). These were first described and classified as coversands by Vink (1949) while Findlay (1965) recognised their importance to the soils of the area.

Included in this section would be the disturbed slope deposits in the Bath area, both foundered and landslipped. Generally these do not affect the terrace deposits; but at Bathampton solifluction lobes have been mapped as terraces.

5) Coastal landforms :

The following features have been described in the literature :

a) a 30m + O.D. abrasion platform, e.g. at Brean (ApSimon et al., 1961)
b) a 21m O.D. beach and cliff, e.g. at Brean (ApSimon et al., 1961)
c) a 15m O.D. raised beach between Portishead and Clevedon (Palmer, 1931)
d) a 13m O.D. raised beach at Swallow Cliff, Middlehope (Gilbertson and Hawkins, 1977)
e) a raised beach at Walton-in Gordano (ApSimon and Donovan, 1956)
f) a 3m raised beach between Portishead and Clevedon (Palmer, 1931)
g) the Howe rock platform at Brean between 0 to -6m O.D. (ApSimon et al., 1961).

Gilbertson (1974) studied the evidence for these features and undertook a survey of their exact altitudes. He concluded there was evidence for the following succession of coastal landform development :

iv) a Devensian sea level of less than -35m O.D., as determined by the excavated depth beneath the Somerset Levels.

iii) An Ipswichian marine transgression with a maximum wave height of 14-20m O.D., forming a cliff, notch and platform at Holly Lane, Clevedon, Swallow Cliff, Middlehope and Brean Down.

ii) Hoxnian high sea levels with wave abrasion around 30m+ O.D., and notch and cliff features developed at 40-47m O.D.

i) a platform with a cliff and notch feature between Portishead and Clevedon, and from 11-14m O.D., of unknown date and climate.

The sea notch at Holly Lane noted by Palmer and Hinton (1929) has not an obvious correlation with the terrace deposits, especially those of Sheepway and Sheephouse. One of the problems of relating sea level platforms and beach deposits in the Severn Estuary region is the high tidal range of the area. In addition, the natural tendency for river terraces to be related to the bedrock channel means that in the downstream area the terraces have dropped to such a level that they would lie below the level of the Flandrian alluvium.

6) Alluvium :

A wide spread of Flandrian alluvial sands and muds exists under much of the coasts of Somerset and Avon, extending inland to the low lying areas such as the Vale of Gordano, the Somerset Levels, and into the Avon Valley. These deposits are associated with the rapid rise in sea level up to 5000 years BP, and the evidence suggests that the majority were laid down prior to the late Roman period (Lilly and Usher, 1971; Hawkins, 1972).

7) River Terrace deposits :

These form the subject of the present study.

THE BRISTOL AVON RIVER TERRACE DEPOSITS :

Despite the many papers written over the past 180 years, which recorded exposures of the Avon gravels, no overall study has been made in more recent times. There is a need to collect all the available historical information, from a number of scattered references, into one source, and in so doing form a better overall picture of the Quaternary valley deposits. This written data can then be used to complement the new evidence produced during the present fieldwork, and some reinterpretation made in the light of this study.

The literature on the terrace gravels will now be discussed, followed by an examination of the research problems and questions produced by the data.

PREVIOUSLY RECORDED SITES OF SUPPOSED TERRACE GRAVELS :

The stimuli for the previous studies has varied greatly. Much of the material from the Bath area is found in papers from the mid-19th century considering gravel sections exposed during the great railway building era (Weston, 1850; Woodward, 1876 etc.). The finds of faunal remains within these gravels served to fuse the recording into a topic of interest (e.g. Winwood, 1874, 1878, 1888, 1897).

Elsewhere, e.g. at Shirehampton and Chapel Pill, it was the discovery of Lower Palaeolithic tools that sparked off interest and papers generally resulted whenever a new find was made, often also reviewing previous finds, e.g. ApSimon and Boon (1960).

The irregularity of exposures and the chance nature of discoveries meant that few authors had sufficient experience of the gravels to make an overall study. Davies and Fry (1929) and Palmer (1931) both summarise the known sites, attempting to link them into a terrace sequence and to make wider correlations with the Severn and the Thames. They were limited by a lack of long exposures giving stratigraphic information, an adequate dating technique, and a concern to fit the River Avon deposits into a known sequence.

The sites are considered below in order of occurrence downstream from Bath, rather than in any chronological or depositional order. Detailed borehole logs and sections are contained in Appendix I.

SITES UPSTREAM OF BATH :

The summary paper of Davies and Fry (1929) briefly mentions deposits at Melksham. They noted reports of a find of an ox skull in 1839, from Oolitic gravels, while at another site, about 40m O.D., was 0.3-1.0m of flood loam over 1.2m of sandy, fine flint gravel resting on the Oxford Clay. These sites are within the area of the consequent drainage pattern of the River Avon and are influenced by the physiographic setting and geology east of the Cotswold Hills, as discussed in Chapter 1, hence they will not be considered any further.

THE HIGH LEVEL GRAVELS :

The next set of deposits are the high plateau gravels found on Bathampton Down (189m O.D.), Kingsdown (165m O.D.), Farleigh Down (167m O.D.), Freshford (137m O.D.), and Bathford (160m O.D.). Palmer (1931) compared them to the Hampshire Clay-with-flints. Although they have some common features, they have several possible, and different origins. Mainly they are siliceous (predominantly of Greensand chert), barren gravels with a ferrugineous clay matrix, infilling gullies on top of the Great Oolite. Weston (1850) described pockets of this material on Kingsdown ("some rounded and some brecciated Chalk flints in a red clay"), and on Farleigh Down ("drift material mixed with Oolitic debris and hardened by a lime-rich water to a conglomerate"). He noted that where no clay or gravel existed over the Great Oolite, there was a strong ferruginous tint to the upper surface, as if the superficial deposits had been removed.

Winwood (1878) found a layer of flints, again set in a "mass of reddish loam", interstratified between two Oolite beds, in a quarry at Bathford (App. I, Section 1). Here the deposit achieved a maximum thickness, comprising large rounded flints and a few small quartz pebbles. He attributed the deposit to a former Chalk and Greensand cover, now eroded and left only as such residues. Weston (1850) had considered the material to have been deposited in the Early Eocene, before the existing valleys were cut.

Varney (1921) proposed a former east flowing river system which had deposited Welsh rocks on Bathampton Down en route for the Thames basin, although no Welsh rocks have been recorded since. Study by various workers including Richardson (1954), Hawkins and Kellaway (1971), Kellaway, Horton and Poole (1971) and Gilbertson (1974) now suggests that the drifts are either gelifluced remains of former high level drainage material from the Tertiary, or, more likely, glacial deposits left on a continuous Great Oolite plateau, possibly prior to the incision of the present fluvial valley.

The evidence of the topographic setting of the deposits and the very weathered nature of the material have been taken to suggest its great antiquity i.e. an Anglian deposition date.

TERRACE GRAVELS :

Within the later river valley the various terrace gravels were deposited. The village of Freshford lies at the upstream end of the Limpley Stoke Gorge, where the valleys of the Rivers Frome and Avon converge. Moore (1869) and Woodward (1876) reported finds of gravel in a small basin southeast of the village. At Freshford Mill, the 1.5m of gravel contained pebbles of Oolite, chert, Millstone Grit, Carboniferous Limestone, and Old Red Sandstone. Woodward gives a more detailed section from Freshford Station which shows an interlayering of clays, Oolitic debris, and clayey gravel. It was these deposits that produced much faunal material (Moore, 1869; see also Chapter 6).

Woodward (1876) also mentions a deposit in the valley of the ByBrook, West of Box, where a series of up to 2m of clays and loams overlay 1.5m of gravel, (App. I, Section 2).

Downstream of the Limpley Stoke Gorge the ByBrook joins the River Avon on the northern side of the broad floodplain that opens out below the gorge. The Avon appears to have continually moved northwards across this floodplain, leaving areas of gravel to its south. Around Bathampton Station, Woodward recorded 1m of reddish brown clay overlying 2m of very sandy fine gravel.

There are few mentions in the literature of the obvious topographic terraces at Bathampton, but they are differentiated into the Nos. 1, 2, and 3 terraces on the BGS survey.

SITES WITHIN THE CITY OF BATH :

The fluvial gravels will have been exposed many times as the city developed, and most frequently during the cutting of the railway lines. Several gravel pits were also formerly worked. Much of the material has now been removed, or covered with thicknesses of made ground, so that the present day sections through the in situ Quaternary materials are more rare.

The gravel pit at Larkhall is mentioned by Lonsdale (1832), while Moore (1869) and Woodward (1876) give details of a section (App. I, Section 3) with two gravel levels of 2.5 and 4.5m, divided by thick, laminated marls containing locally derived fossils. Mammal bones were retrieved from the basal part of the lower gravel (see Chapter 6), but no further descriptions of the enclosing deposits are given.

Moore (1870), which is quoted by Richardson (1929) and Donovan (1960), reported on sections exposed during building work in the city. At Pulteney Road (App. I, Section 4) there was 6.5m of prehistoric and historic remains (including a peat band) above 3.5m of mammaliferous gravels set on the Lower Lias Clays. A well dug at the Royal Hotel showed 2.5m of freshwater clays and recent debris over 1.2m of gravel with faunal remains (App. I, Section 5). Other sites where gravel was exposed include Westgate Street, the Mineral Water Hospital, the Market Place, and to the south of the Royal Crescent, where 4m of mixed gravel lay below 0.3m of sandy loam, said to have contained mammalian remains (Woodward, 1876).

Additional information exists about a railway cutting on the Bath and Evercreech line, reported in some detail by Winwood (1874 and 1888). He described a gravel knoll between Twerton jail and Bloomfield Place, through which the Morefield/Moorfield cutting was dug. Details of a section of the cutting are given in App. I, Section 6. The gravels occupied a trough-like depression in the Lias Clay, with their maximum thickness being at the highest point of the knoll, and thinning and becoming patchy towards the Bloomfield Place Tunnel.

Winwood thought he could detect changes in the distribution of lithologies throughout the gravels : at the top were rolled pebbles of Liassic and Oolitic limestones, below this rolled and subangular flints and occasional Chalk, lower still rounded and subangular Carboniferous Limestone and sandstones, then at the base, subangular clasts of quartzose, greenish sandstone and large boulders of Inferior Oolite (one measured 740 x 700 x 300mm). Winwood concluded that these boulders must have been deposited by ice, and quoted Charles Moore as having found deep grooves cut into the surface of the Lias Clays, below the gravels. Mammalian remains were removed from an arenacous clay within the gravels, and some land and freshwater shells from a sand band above this.

With the discovery of the gravel, two pits were opened to exploit it. The one at Bellott's Road, Twerton, is not described in detail, although generally it is considered part of the 50 foot (15m) Avon Terrace. There is more information about the Victoria gravel pit, which was the subject of a Geologist's Association Meeting in 1941 (Cox et al., 1941). Various sections of the pit have been described by different authors. Winwood found interstratified gravels, consisting of Oolitic, Liassic and Carboniferous limestones, Chalk flints, cherts, and Millstone Grit, together with "black bands" (iron staining or peat rich layers?), and again large boulders at the base (App. I, Section 7).

Palmer (1931) described the material in the Victoria Pit as being of sandy, unstratified, fine gravel, over laminated sandy marl and fluvial gravels, which compares well with the section drawing made in 1948 by Dr. G.A. Kellaway and included in Chandler et al. (1976). The undisturbed gravels are shown overlying Lower Lias Clay, which has been contorted and faulted during a glacial period prior to the terrace gravel deposition.

Winwood (1897) also studied material from Boyce Hill (near Weston Station), where there were several excavations between the railway line and the river. He gives details of three sections (App. I, Sections 8, 9, 10) and two photographs of these. In addition to the typical range of Jurassic lithologies, the material also included Carboniferous Limestone, Old Red Sandstone, Isastrea, Cretaceous flint and chert, Old Red Sandstone conglomerate and Dolomitic Conglomerate, and a reddish quartzite. Some mammalian remains were found in a band of yellow clay (cf. the position of the Morefield Cutting faunal remains).

On the BGS Sheet the Bath Terrace deposits are marked as follows :

<u>No. 3 Terrace</u> :	Twerton (Victoria Pit, Morefield Cutting) at 42-50m O.D.
<u>No. 2 Terrace</u> :	Larkhall at 30-37m O.D.
	Villafields and Dolemeads at 15-30m O.D.
<u>Nos. 1-2 Terrace</u> :	Lambridge at 23-27m O.D.
	East Twerton (Bellott's Road Pit) at 15-23m O.D.
<u>No. 1 Terrace</u> :	South of Larkhall at 15-23m O.D.
	City centre sites at 15-23m O.D.
	Boyce Hill (Lower Weston) at 15-30m O.D.

Chandler et al. (1976) attempted to date the Bath terraces in order to interpret the development of the valley slopes. Since there was "insufficient evidence from the Avon terraces themselves to date the sequence with certainty", they correlated the deposits with those of the Rivers Frome (Stroudwater), Severn and Warwickshire Avon. The Twerton (No. 3) terrace was thought equivalent of the Whitminister Terrace of the Frome and the Kidderminster Terrace of the Severn, and dated to the Ipswichian/early Devensian. The No. 2 Terrace is placed in the Mid-Devensian, by reference to the fauna of the Caincross and Severn Main Terraces, while the No. 1 Terrace is considered a late Devensian infill of the buried channel, which had been excavated during the full glacial.

<u>SITES BETWEEN BATH AND BRISTOL</u> :

At Newton St. Loe (around the area of the present A4/A36 junction, the BGS maps show Head over Keuper Marl, and indeed when ploughed the fields reveal large amounts of hillwashed grey limestone. In addition, the 1930 Edition of the 25" to 1 mile topographic map, and the later geological sheets, mark an old gravel pit at 23m O.D. just north of the LMS Railway

Line, which presumably supplied the railway line. Woodward (1876) noted a thin deposit of gravel at the Newton St. Loe crosspost turnpike at about 25m O.D., overlying red Marl. This contained remains of horse and elephant. He also mentioned a higher terrace of alluvium to the west.

Davies and Fry (1929) briefly refer to a 12m high hill of gravel on which the Roman Villa of Newton St. Loe was built. This site was south of the A4 road, and on the line of the GWR railway at 30m O.D. The gravel also had elephant bones in the basal part.

These deposits suggest that in addition to the Head material there is an area of fluvial terrace gravel and indeed this was confirmed during excavations at the A4/A36 road junction in 1968 (Hawkins, pers. comm.).

Downstream the next site of interest is at Kelston, on the north side of the river. Here Davies and Fry (1929) mention a band of flint and chert pebbles lying across a field at 76m O.D., although the location of the field cannot be identified. They classed the deposit as part of their "high terrace" which was predominantly of flint and chert gravel, lying between 76-91m O.D., as found also at Conham and Abbots Leigh.

Fry (1956) reported that to the south of the village of Kelston at 46m O.D., resting on the Lower Lias platform, is a decalcified gravel, consisting of Greensand chert, flint and quartzite pebbles. To the northwest of the Church was an area of "unaltered river gravel", while west southwest of the Church, surface finds of 12 Lower Palaeolithic tools of Greensand chert were made in 1930.

The area is recorded on the geological maps as Head over Lower Lias Clay with two small patches of sandy gravels marked northwest and southwest of the village at about 46m O.D.

Woodward (1876) stated that the village of Bitton was situated on a gravel patch, and Fry, working in the gravel pit southwest of the village, at HolmMead Lane, found gravel containing examples of Greensand and Tertiary faunas (an Eocene shark's tooth is preserved in his collection), but no Quaternary remains. No description of the clast material is given, although this area is marked as the No. 1 Terrace. A photograph of the old gravel pit, taken in 1964, is included with the discussion of the area in Chapter 4 of this thesis (Photo 4.21 : Hawkins, pers. comm.).

Stidham Farm is situated on the slopes above the south river bank. This site has been famous for its gravel deposits for many years and several pits have been excavated to exploit the material. At 21m O.D. Davies and Fry found 2m of medium Jurassic limestone gravel, including some Carboniferous Limestone, Pennant and Limestone Grit, flint and chert, in a sandy matrix. The gravel was heavily iron stained at the base, where it met 0.3m of large angular limestone blocks in a grey clay matrix, set on Lias Clay bedrock. No faunal remains are recorded at Stidham.

Woodward (1876) mentions fluvial limestone gravel with sand lenses, in a pit near Londonderry Farm, on the road between Keynsham and Willsbridge. Much useful information on the basal gravels can be obtained from Donovan's paper of 1960, which details borings made in the Keynsham area, for a Ranney Well south of the Fry's Somerdale factory, and along the route of the Keynsham bypass. Donovan's borehole records are given in App. I, Sections 11-16. He found three groups of deposits :

a) gravel and coarse sand resting on the rock valley floor,
b) clay or marl, silt and sand, with much plant debris, peat and shells,
c) brown to red-brown clay, loam and silt (the alluvium).

The gravels were well rounded with pebbles up to 150mm length, mainly of Jurassic limestone but also including Carboniferous Limestone, Greensand chert, and flint. Donovan proposed that since the angle of repose of the gravels was likely to be the same as that of the present day river, then it would have been necessary for there to have been a greater volume of flow to transport the gravel. The clays above the gravel showed some evidence of an association with the latter, since one borehole revealed the upper 1.3m of the gravel to contain much silt, shells and wood. Donovan suggested that between the gorges there were marshy valley plains in which gravel barriers or solifluction deposits periodically dammed the accreting floodplain.

Donovan (1961), using the data available at the time, tentatively correlated the gravels with those found by the Severn Tunnel (Richardson, 1887), purely on the basis of the lack of silt and clay in both deposits. This made them possibly of Worcester Terrace age (Wills, 1938) and equivalent to the Ponder's End Aggradation of Zeuner for the Thames Valley (Devensian age).

The clays over the gravels were suggested as being prior to Post-glacial Zone V (Boreal), purely on the fauna from what he assumed to be the equivalent beds above the gravels at Bath.

The next site downstream is at Brislington and St. Anne's. At 46m O.D. above the Conham Gorge are thin patches of gravel consisting of Greensand chert, flint and quartzite. App. I, Sections 17 and 18 show the deposits in a drainage trench at Jersey Avenue, Brislington (Fry, 1956). The deposits are marked on the geological maps as Head, although they are often referred to as decalcified remains of terrace material (Fry, 1956).

The finding in 1930 of eight Lower Palaeolithic tools at St. Anne's Park, and twenty more at Brislington House, increased the importance of the deposits to an understanding of the Quaternary history of the valley, especially since they are shown to be very similar to the material from Chapel Pill, as will be discussed below.

SITES WITHIN THE CITY OF BRISTOL :

The intensive building activity within the city means that much of the material is removed by excavations or covered by made ground. The alluvium in this part of the valley will probably overlie any terrace deposits and thus further limit their chance of exposure. However several scattered sites where gravel was encountered have been published.

Generally they consist of brief mentions of the gravel, e.g. Sutcliffe (1882) speaks of a pebble bed in the alluvium, between High St. and Redcliffe Hill, around 3m below O.D. At Lawford's Gate (App. I, Section 19), a red loam with frost shattered pebbles of Greensand chert was excavated (Fry, 1956). If this is not a disturbed material, it suggests a till deposit more than a true terrace accumulation. Fry (1952) also reported an alluvial section from Broad Mead on the site of the Marks and Spencers building (App. I, Section 20), where 1.3m of gravel was found resting on Keuper Marl and with its top surface at about sea level. Over this gravel was 8m of estuarine and marsh clay. This thickness of alluvium was paralleled in Union Street where a well, dug in 1906, found 1m of gravel on the Keuper Marl, below 10m of silt and clay.

Three more sites showed deep buried gravels : at George's Brewery there was 2m of gravel on the Triassic Marl at 1.3m below O.D., and at Bathurst Wharf, 2m of clay and gravel over the Trias at 4m below O.D. with a massive 11m thickness of blue clay above (Richardson, 1930). Bright (1817) mentions waterworn pebbles and rounded flints at the base of the "New Cut", just above bedrock, while Stoddart (1870) reported two gravel beds in the Cumberland Basin with 1m of stiff brown clay between them (App. I, Section 21).

These deposits are the basal gravels of the River Avon (Hawkins, 1962, mentions a thin terrace remnant covered by the alluvium, resting on a rock bench on the north side of the river channel, at Hotwells).

Around Hotwells the gradient of the river channel changes. The following depths to bedrock are known :

Batheaston	+ 15.2m O.D.
Pulteney Road, Bath	+ 10m O.D.
Keynsham	+ 0.6m O.D.
Cumberland Basin	- 10.5m O.D.
Hotwells	- 12m O.D.
Avonmouth	- 19.7m O.D.

The resultant profile for the River Avon is shown on Fig. 2.1, with the average gradient becoming 3° steeper downstream of Bristol. The knickpoint at Hotwells thus represents a rejuvenation to a new base level.

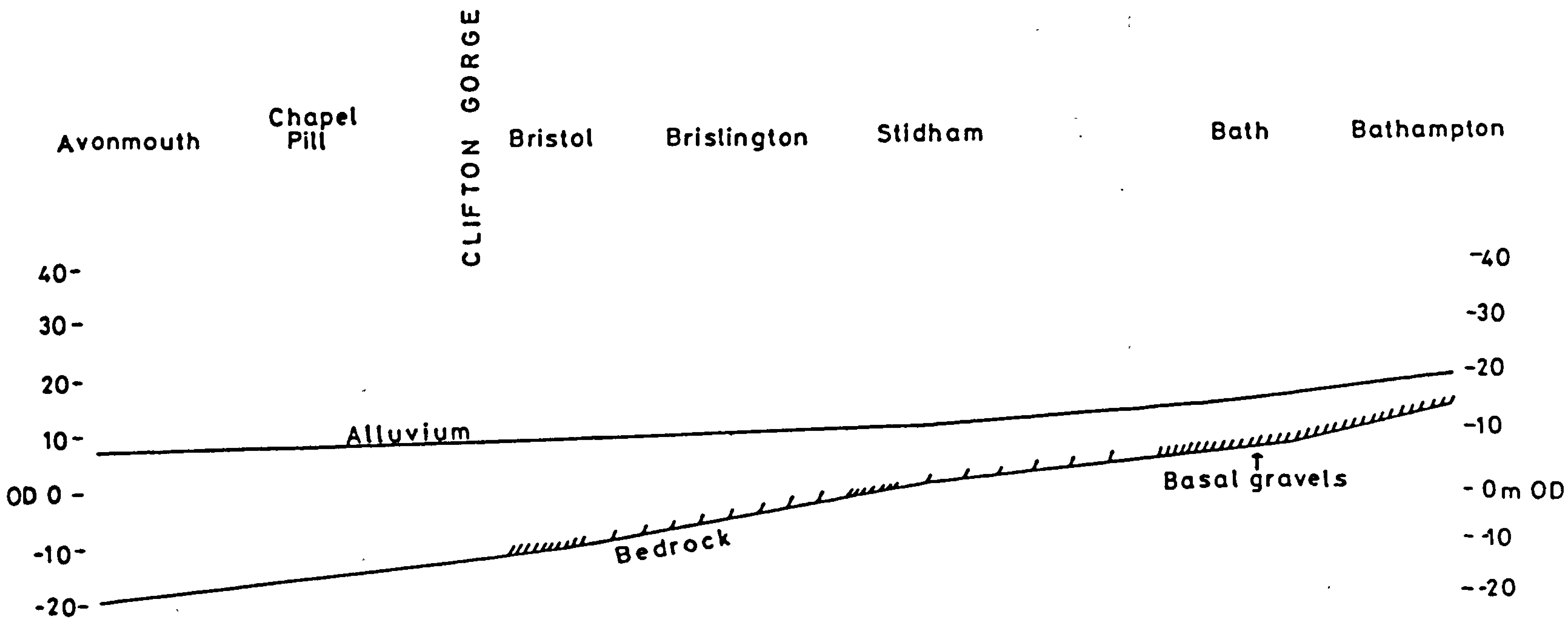


Figure 2.1 : Depth to bedrock, basal gravels and height of the modern alluvium, Lower Bristol Avon

Following the last glacial phase, the rise in sea level has caused a build-up of alluvium within the river valley related to the heightened base level. There may be a retarding effect as the river profile adjusts to the rise in sea level, as indicated in Hawkins (1984).

SITES DOWNSTREAM OF BRISTOL :

The River Avon flows through Bristol, turning sharply north at Hotwells and entering the Clifton Gorge. On the plateau above the river are recorded a further set of high level gravels. At Abbots Leigh and Leigh Woods, about 76m O.D., flint and chert gravel remnants were recorded by Davies and Fry, and paralleled on the east side of the river at Black Rock Quarry by "rolled and river-worn flints". Colbourne et al. (1973) investigated exposures in Leigh Woods and on the Failand Ridge, and concluded that the material was of glacial origin due to its "lack of sorting, wide range of particle sizes present and the frequent presence of erratics".

Further downstream of the Clifton Gorge, the river flows round the Horseshoe Bend. On the south bank, in the fields of Chapel Pill Farm, between 30-60m O.D., the surface is strewn with Greensand chert, quartzite, flint, sandstone and limestone pebbles. From the surface of this thin gravel deposit some 400 Lower Palaeolithic tools have been recovered, predominantly made of Greensand chert.

The area is marked on the geological maps as the No. 2 Terrace, and indeed two topographic levels can be noted as benches above the Avon at 15m and 30m O.D. The gravel deposits rest over these benches.

Lacaille (1954) gives a section (App. I, Section 22) above the railway line near Ham Green Halt, and describes the material as "unstratified detritus from decalcified gravel". Contained within the deposit were "angular and shattered stones including bleached flints ... jumbled in great confusion and mixed with muddy looking dark loam". The artefacts are also in a very weathered state, because they have undergone prolonged exposure. He assessed it as thinly laid periglacial ground debris or Head.

By whatever means, the worked cherts have become incorporated into the gravels then suffered weathering, erosion and later ploughing. This may have aided the removal of the more soluble clasts from the material and brought the gravel sized clasts nearer to the surface of the deposit. The question arises of whether the original gravel was a terrace deposit or drift material similar to that found in Leigh Woods, the Failand Ridge etc.

The deposits on the opposite bank at Shirehampton are less weathered. A number of artefacts have been retrieved from these, but in spite of their numbers (more than 23 in total from at least fifteen sites), only three sections through the deposits are published (App. I, Sections 23-25), Davies and Fry (1929), Lacaille (1954), and ApSimon and Boon (1960).

The section described by ApSimon and Boon from the High Street, Shirehampton, is perhaps the most complete and interesting. They classify Beds 1-5 (gravels with sandy beds above) as waterlaid and fluvial (as opposed to marine) due to the lack of appropriate faunas. Beds 6 and 6a are hillwash formed under periglacial conditions. However if the lower deposits are considered in detail, the 1.2m of gravel, though lying mainly horizontally, is not stratified, has local sandier beds, and is of relatively well-rounded clasts. There is a range of rock types, predominantly Jurassic limestone, flint and chert. Above this gravel are two levels of horizontally laid pale yellow earthy sand, separated by a reddish sand, again horizontal, and more "earthy" with some gravel in the upper 80mm. These seem remarkably like coversands laid down by winds scouring a periglacial area, and the gravels below may represent outwash material rather than true terrace.

The deposits are comparable with those from Holly Lane, Clevedon, and the Kenn area, where Gilbertson found coarse silty or sandy deposits of variable sorting and uniform thickness with occasional boulders.

The sequence described from the High Street is truncated by a solifluction deposit on top of the sands. ApSimon and Boon interpreted the gravels and sands as part of a normal fluvial regime, with beds 3-5 being deposited by slower currents than the previous two layers.

Other sites in Shirehampton confirm the existence of gravels overlain by a sandy loam, e.g. at Penleaze House, Penpole Point and Walton Road, where the soil includes shattered chert and rests on a stiff clayey loam, containing chert, flint and quartzite. This material resembles that described at Chapel Pill. The geological map marks these sites as the No. 2 Terrace and differentiates between these and a No. 1 Terrace around Myrtle Hall.

The final major site of supposed terrace deposits lies in the middle of the recent Severn alluvium in the Portbury area. Two small topographic rises, at Sheepway and Sheephouse Farm, mark where a thin gravel caps the flat tops of Triassic inliers. Hawkins (1968) interpreted the gravel of the area as of three types :

The first are those between 9-15m O.D. (No. 1 Terrace on the geological maps), with a large variety of rock types apparently transported from within the Avon catchment Basin. On altimetric evidence, comparing these deposits with gravels from the Severn and Vale of Gordano, Hawkins dated them to the Ipswichian (No. 2 Severn Terrace). The second group, forming the majority, rest around -3m O.D. and act as a cover to the Marls. The third group would seem to be locally derived from the Failand Ridge, because of their location, and they rest around 1m O.D.

Fry (1956) reports that in 1931, six very abraded Lower Palaeolithic tools were found between 8.8-10.3m O.D. (and therefore in the first group of gravels) around Sheephouse Farm.

THE PRESENT RESEARCH :

The major problem that emerges from the above discussion of the literature is one of the inadequate recording of many of the temporary gravel exposures and chance finds of fauna and artefacts. The opportunity arose during the present study to excavate in certain areas of interest, and thus to enable a detailed description and sedimentological comparison of the materials found. The evidence for the distribution and interpretation of the faunal remains and Palaeolithic cultural material has also been re-examined.

The present research was undertaken against the background of the recent acceptance of the glaciation of the area and the wide ranging consequences of this. From the outset, no attempt was made to fit the Avon terrace deposits into the "established" Severn and Thames sequences, but rather an examination of the available evidence from each site was undertaken and localised correlations of events determined. The altimetric records of the gravels are considered relevant only within the Avon Valley and Severn Estuary, since they are unlikely to bear any close relation to physiographic, fluviatile and marine controls operating, for example, in the Thames Valley during the Pleistocene.

The detailed sedimentary information and conclusions of the study of the Avon Valley deposits can be added into the picture that is now emerging for this area of Southwest England during the Quaternary period.

CHAPTER 3

TECHNIQUES OF FIELDWORK AND ANALYSIS

FIELDWORK :

Throughout the period of study a record was kept of all new excavations and exposures of Quaternary deposits in the area of the Bristol Avon. Partly due to financial cutbacks, these exposures were less prolific than anticipated at the commencement of the research. However, much valuable information was gained from observing site investigation work at Bathampton, Chapel Pill and Lewins Mead in Bristol, the excavation of house plots at Ham Green, and the clearance of the roadside ditch on the A369 near Sheepway.

To complement this data, a series of trial pits were dug, both by hand and mechanical excavator.

Initially a study of the sites of interest was made by reviewing the available literature and the British Geological Survey maps of the geology of the Bristol Avon area. Once permission had been obtained from the relevant landowners, the ground was walked. Where appropriate and possible, the deposits were selectively augered and excavated.

As acknowledged earlier, the trial pits excavated as part of the present study were financed with a grant from the Maltwood Fund for Archaeological Research in Somerset (1982). The excavations and resultant collection of data would not have been possible without this funding.

EXCAVATIONS : (Fig. 3.1)

In view of the nature of the deposits, the hand augering was done using a 1.2m long auger. To drill through the gravels encountered would have involved a large diameter auger, and mechanical equipment would have been necessary. Even using the large auger it would have been possible to obtain deposits at various depths, with little information on the structures involved. The small auger however was of value in determining

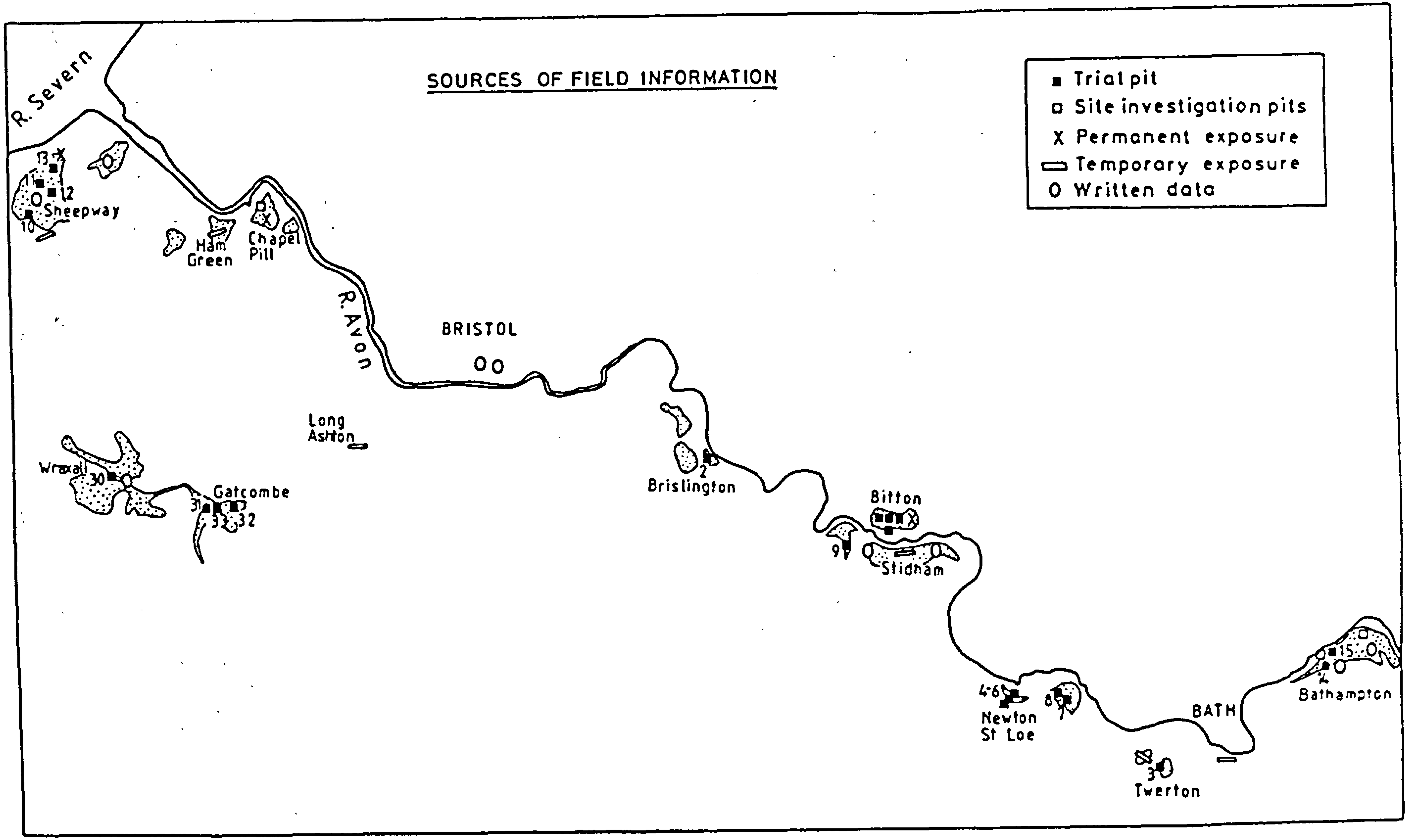

SOURCES OF FIELD INFORMATION
■ Trial pit
□ Site investigation pits
X Permanent exposure
Temporary exposure
O Written data
R. Severn
R. Avon
Sheepway
Ham Green
Chapel Pill
BRISTOL
Long Ashton
Wraxall
Gatcombe
Brislington
Bitton
Stidham
Newton St Loe
Twerton
BATH
Bathampton

Figure 3.1

the presence or absence of gravel beds and hence helped to decide where it was desirable to place pits.

Hand pits were dug at Twerton, Keynsham, Brislington, Chapel Pill, and Sheepway Gate Farm because of the shallow nature of the deposits or the inaccessibility of the sites for machine work (Chapel Pill and Twerton are within railway cuttings).

The hand dug pits were generally 2m x 1m in area and up to 1m in depth. One advantage of excavating by hand is that the deposit can be observed in close detail as excavation proceeds. When sampling, however, it is sometimes difficult to obtain large representative bags of material after the faces have been cleaned and described, as is necessary before selecting the sampling positions. A further advantage of the hand dug pits is that landowners prefer them since the area of disturbance is much less than with a mechanical excavator. In terms of the time involved, on arable land, a 2m x 1m x 1m pit can be dug in one day, with the study and the backfilling necessitating a second day's work.

Trial pits dug with a mechanical excavator are obviously the best method of studying larger sections to depth. Their main disadvantage is not geological, but rather the difficulty of obtaining permission to dig from landowners, when there is no commercial gain.

The trial pits were of roughly 4m x 1.5m area and continued to bedrock, where this was reached within the limits of the mechanical excavators (generally about 4m). In some cases the pits became infilled with water, the depth and speed of infill being related probably to the local ground water level and frequently to the proximity of the river. Therefore the deposits beneath the ground water level could only be studied from material acquired from the bucket of the excavator. The sides of those pits into which water ingress was rapid, were extremely unstable due to the high permeability of the sandy gravels. The great advantage of mechanical excavation, once the sections had been cleaned, was the facility to examine the structure of the deposits and the size of the pit enabled sufficient quantities of gravel size material to be sampled easily.

SAMPLING :

During the augering no samples were taken as it was considered that contamination would be inevitable and the quantity produced insufficient and unrepresentative. From the trial pits, large bag samples, sometimes up to 10 kgs in size were taken. After selecting the sampling zone and cleaning an area of the pit face, a sample was taken, as far as practicable, to give a "cube" of material. Unfortunately some pits were not sufficiently stable for samples to be collected from the sides and it was necessary to take them from the excavator bucket. Care was taken to work closely with the digger driver to obtain the best samples from the near section of the pit at the appropriate level. At least one sample was retrieved from every layer change, while in lengthy exposed sections, such as at Stidham Farm, several samples of each layer were taken so that lateral changes were taken account of.

SURVEYING :

The ground level height of the exposures and deposits is vital to their spatial interpretation, although the stratigraphy of terrace deposits is no longer thought to be so inherently related to their height above sea level. The overall heights of the deposit areas were obtained from the 1:10560, 1:10000 maps and the 1:2500 plans. The various trial pits and exposures were determined from the nearest bench marks with a dumpy level.

REPORTS :

Data was obtained from the following site investigation and excavation reports :-

a) Bathampton - site investigation by Soil Mechanics for Alexander Gibb and Partners prior to the A46 Bypass.

b) Twerton - excavation of a pipeline trench along the Morefield Cutting by SW Gas.

c) Stidham and Avon Farms - excavation of a pipeline trench by Wessex Water Authority between the Saltford and Keynsham sewage works.

d) Cattle Market Road, Bristol - site investigation due to road subsidence.

e) Lewins Mead - site investigations by Geotesting prior to building of an office complex.

f) Sheepway/Portbury - site investigations prior to the siting of the Royal Portbury Dock.

MAPS :

A check was made of the older topographic and geological maps of the area. This was useful for obtaining information on positions of former gravel pits, such as at Bathampton and Newton St. Loe, and also for compiling the data of exposures etc. not included on the later editions.

LABORATORY METHODS

PARTICLE SIZE ANALYSIS :

Sample preparation : The samples taken in the field were generally of 10kgs weight for gravels, but only about 1kg in sandy material. These were then successively quartered to produce a subsample of reasonable quantity for analysis. The size of this subsample varied with its components : around 2000g was needed for samples predominantly of gravel, whereas less than 100g was required for silt and clay samples. Quartering was done on a large plastic sheet, where the material was mixed, formed into a cone-shaped pile, split into four segments, and two opposite quarters removed. The rest was then remixed and the process repeated until a subsample of the correct size remained.

The material for analysis was left to dry at room temperature, although some samples of gravel, with an estimated less than 10% clay (which therefore did not require pipette analysis), were dried in an oven at 95°C. The initial dry sample weight was then recorded.

Small samples were placed in a beaker, while buckets were needed for the larger coarse samples. They were covered with deionised water, and left immersed for up to three days, being stirred occasionally to aid disaggregation. To complete dispersion, the clay rich samples required the addition of 10-20mls of a 10% solution of Decon 90.

Wet sieving : The larger gravel clasts were lifted out of the sample container and washed on a -1ø sieve, over a dish, and the coarse fraction then placed in a large evaporating dish. The remainder of the sample was gradually washed on a 4ø sieve, and the sand and gravel dried in an oven and weighed.

The resultant amount of clay, silt and water was measured and made up to the nearest litre with more deionised water (generally 5-6 litres resulted). The fine fraction was kept in suspension with a mechanical stirrer whilst 1 litre was removed and placed in a sedimentation cylinder. The remainder was oven dried in evaporating dishes to provide a check on the accuracy of this splitting, and to give the total weight of mud sized fraction.

To help prevent flocculation of the sample in the sedimentation cylinder, 10mls of 10% Decon 90 (weighing 0.06g) was added, and the mud allowed to settle out of suspension. As a sample of 10-20g is best for pipette analysis, most samples required further splitting (occasionally to 1/32 of their original size). In samples where flocculation was a problem, adding more than 10mls of Decon 90 had little additional effect; however in general in the terrace muds the dispersion was reasonably effective.

The sedimentation cylinder was then placed in a tank of deionised water kept at 25°C by means of a thermostat and heater. The water is kept in motion by a stirrer to deter the formation of temperature gradients. The cylinder was left overnight to allow the sample to reach 25°C.

The preparation technique described above would have been unrealistic for some samples, in terms of the time involved and the amount of liquid required. For example, some of the tills and solifluction samples contained 30-40% mud, and material of up to -7 to -8ø. To give an accurate statistical analysis of these samples a very large amount would have to be washed, producing many litres of mud/water. The following method was adopted, which proved satisfactory. A sample of around 2-3000g was dried and the original weight recorded. A representative subsample was then removed and weighed, although it is appreciated that a small subsample can never be totally representative. The subsample was then washed on a 4ø sieve, and the dried weight of sand and gravel recorded. A litre of the resultant mud was taken for pipette analysis. The original large sample (now minus the subsample) was then washed using tap water over a 4ø sieve, and the mud fraction discarded. The cleaned sand and gravel then formed the basis for the dry sieving from 4ø to -8ø, whilst the pipetting of the subsample gave the relative percentage of material between 9ø to 4ø. Before any computing was done, the two sets of samples had to be related to each other, e.g. generally the subsample was around 10% of the large. Whether the subsample was representative could be checked by the calculation of the sand and gravel : mud ratio of each of the sievings. In practice this never deviated by more than 5%. The weights for the 9ø to 4ø sizes were multiplied up to give the amount in the whole sample; these amounts were used to compute the statistics of the sample.

Pipette analysis : As there is some question of the accuracy of the pipette method, several methods were tried and compared (Griffiths, 1967; Galehouse, 1971; Shackley, 1974; Catt, 1978). Since the Bristol Avon samples have all been measured using the same technique, the results are comparable.

The pipette method is based on the principle of removing liquid from the sedimentation cylinder at successive depths and times to record the concentration of mud in the liquid as it settles from a state of complete suspension. The weights of mud from each removal correspond to the amounts of successively finer grades of material that are still in suspension. The technique involved the following removals :

Withdrawal depth	Time	Largest Ø size still in suspension
200mm	20 secs	4.0Ø
200mm	1m 41s	4.5
150mm	2m 30s	5.0
100mm	3m 22s	5.5
100mm	6m 45s	6.0
100 or 50mm	27m 1s or 13m 3s	7.0
50 or 25mm	54m 2s or 27m 1s	8.0
50 or 25mm	3hr 36m or 1hr 48m	9.0

These figures are based on Stokes Law of settling velocity, with the fluid medium at 25°C and the density and viscosity taken as 1.

A standard Andreasen pipette was set up in a water bath at 25°C. The pipette was attached to a framework which allowed horizontal movement across the tank and drew up a 20ml sample. It was wound vertically up and down on a graduated strut which facilitated reading of the depths for withdrawal.

The procedure for analysing three samples at a time was as follows :

The sample cylinders were set in the tank at the correct concentration and left overnight to achieve the correct temperature. Eight 30ml evaporating dishes were cleaned and dried ready for each sample. Next morning the first cylinder was removed from the tank and hand shaken for three minutes to cause total dispersion of the sediment. The clock was started simultaneously with the cylinder being replaced in the tank. The pipette had been lowered into the cylinder. It was then wound down 200mm and 20mls sucked out after 20 seconds had elapsed. This was emptied into the first of a numbered sequence of evaporating dishes, before the pipette was flushed out completely with deionised water to ensure the total mud was collected. As pipetting progressed, the dishes were placed in an oven at 95°C.

The 4.5, 5, 5.5 and 6Ø samples were then taken at the appropriate times, removal always beginning on the second calculated from Stoke's Law; only 1-2 seconds was needed to remove the sample.

At this point the second cylinder was shaken and the 4-6Ø withdrawals made. Finally the third cylinder was shaken and completed to 6Ø before the 7Ø measure was taken from the first cylinder (after 27m 1sec). In this way three samples could be analysed to 9Ø within 2½ hours. The samples were dried and weighed. In this way, six samples could be completed in one day, and the tank filled with 6 further samples and left overnight to reach the correct temperature.

Statistical calculations : The calculations of the amount of mud in a sample are based on the weight of the sample in the first withdrawal, which assumes total dispersion. This weight is multiplied by 50 to give the amount per litre, and account taken of the amount of Decon 90 and number of dilutions.

The dry sieving of the sand and gravel fraction was carried out by placing the washed and dried samples in the top of a sieve stack. The stack was in intervals of whole Ø units for the coarser gravel samples, and in ½Ø intervals for those of finer grades. The sieves were placed on a shaker for 15 minutes, with some of the larger amounts requiring 20 minutes shaking. Pebbles of greater than -5ϕ were sieved by hand, and all the size grades then individually weighed and recorded as cumulative amounts.

The computing used a standard particle size distribution program as designed by the Sedimentological Section of the Geology Department of the University of Bristol, and produced a wide range of statistical measures on the samples. These included the cumulative frequencies of the grain sizes from 9ϕ to -8ϕ, in both tabular and graph form, the sand and gravel to mud ratio, and a histogram of the amounts in each ϕ size grade. The sedimentary statistics calculated from these amounts included Folk and Ward Mean, Sorting, Skewness, and Kurtosis, which were ultimately those used for the comparison of the samples.

MEASUREMENT OF SIZE AND SHAPE OF THE PEBBLES FROM THE BRISTOL AVON GRAVELS :

A study of particle morphologies was undertaken, which involved making various measurements on the individual pebbles from the gravel samples, and computing these figures through standard formulae to give a series of shape parameters. Hence the samples could be compared numerically and some suggestions made concerning their dynamic behaviour during transport and deposition.

The background study and methods used are more fully described in Chapter 5.

Molluscs and foraminifera :

Faunal material was only found in a few samples. Coarse gravels, deposited by fast flowing water, are not the best sediment for the preservation of delicate shell material, and as anticipated the examples found in the present study were mainly from silts and clays overlying the main gravel deposits. Acidic conditions also tend to destroy any calcareous remains (Coope, 1977).

In samples where shell material was noted, it was removed and studied as follows. The material was washed through a 4ϕ sieve and the residue air or oven dried. The material was then dry sieved through a nest of -1ϕ, 0ϕ and 1ϕ sieves. The debris held on each sieve was placed on a black sheet of paper and sifted through with two paintbrushes, one larger for moving the sediment and one of 00 size for removing the shells with its dampened point. They were then stored in glass phials for study. The samples studied were generally those obtained for particle size analysis; an extra amount was washed when shells were seen to be present yet the numbers of molluscs retrieved was too few for counting.

The sediment finer than 1ϕ was then checked using a low power stereomicroscope for any remaining small molluscs. In practice very few shells were found in this way. In both cases broken shells were collected as well as whole specimens since the apices are often sufficient for identification and counting.

A number of samples of sandy silts and clays taken during coring through the Burtle Beds in the Somerset Levels at Shapwick and Meare Heath were found to contain foraminifera. These samples were analysed as follows. Mud was removed by washing on a 4ϕ sieve, then the residue dried and sieved through a 0ϕ sieve (1mm) to obtain the size fraction that would include most of the foraminifera. For separation, most methods rely on the shells being lighter than quartz sand. Cushman (1948) suggests three treatments :

a) spinning the material in water on a watch glass to leave the sand in the centre and the foraminifera on the edges;
b) shaking the sediment with water in a tall receptable and successively decanting the upper portion, which will contain the foraminifera;
c) sprinkling the dry, heated sediment onto cold water to float off the air-filled shells.

A second group of methods involves heavy liquids, formerly using carbon tetrachloride (sp. gr. at 20^{o}C = 1.577) (Gibson and Walker, 1967), but more recently, in view of its greater safety, trichloroethylene (TCE) (sp. gr. at $20^{o}C = 1.478$). In this case the samples are sprinkled into a separating funnel with a tap at the base and containing 100mls TCE. When the sediment has been allowed to settle through the liquid for 30 seconds, the basal portion is drained off into a filter cone. The cone is rinsed thoroughly with acetone to leave sediment on the filter paper. The mixture of acetone and TCE is re-separated to retrieve the heavy liquid. The top portion of the liquid is also drained off and washed to leave the lighter material, mainly of shells and organic matter. Although this method is simple in theory, in practice it requires around four hours work to separate sufficient sediment from one sample to check for fossil material. Its success at separating the foraminifera was checked by scanning the heavier sediment under a low power stereomicroscope, which was found to contain some of the heavier and larger foraminifera, and those that were sediment filled. Therefore selection by weight and species was occurring.

Since none of the samples was particularly rich in faunal material, it was especially important to find a method that could separate a large amount of sediment, relatively quickly and effectively.

The best method was found to be simply heating the sediment and floating it on cold water, since this was quick, and meant that large amounts of sand could be scanned to see if any foraminifera had been preserved at all. If shells were found to be present, the sand was rapidly brushed over under the stereomicroscope.

Once located a shell was lifted off with the damp point of an 00 size paintbrush and placed on a recessed cardboard microscope slide. The surface of the slide was black and painted with water soluble glue so that the foraminifera would adhere to it. The shells were placed on the slide in their species groups to allow rapid identification in a later study. This preliminary sorting of species was accomplished by using Jenkins and Murray (1981) and Murray (1971) as references.

CHAPTER 4

FIELD INVESTIGATIONS (1981-1985)

1. BATHAMPTON

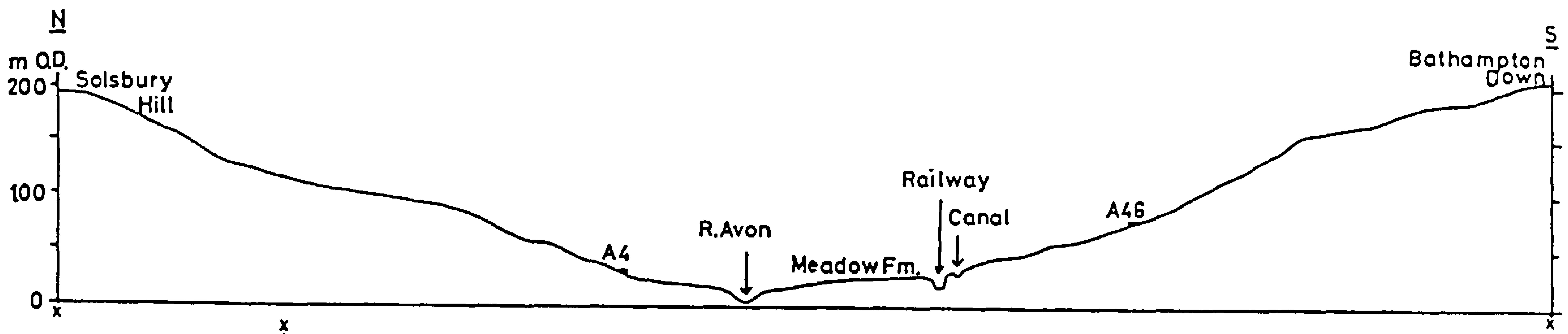
Introduction :

Between Bradford-on-Avon and Bath, the River Avon runs northwards through the Limpley Stoke Gorge before turning west into the broad valley around Bathampton. Here the tributaries of the Lambrook, Bybrook and Swainswick streams join the Avon before it enters the city of Bath (Fig. 1.1).

As explained in Chapter 1, this is an ideal place to begin the study of the terrace gravels, downstream of the gorge that separates the strike stream and its terraces above Bradford-on-Avon from those built up as the river crosses the varied downstream geology.

The Avon floodplain (20m O.D.) lies between the slopes to Bathampton Down (204m O.D.) and to Little Solsbury Hill (188m O.D.) (See Photo 4.1 and cross section in Fig. 4.1). The 1:10560 geological sheets indicate the higher slopes of the Downs to be a series of hummocks formed of clay slips mixed with limestone debris. Below 80m O.D. the gradient becomes more gentle and by 40m O.D., where the highest level of gravel deposition is observed, the slope graduates to the floodplain in a series of topographic terraces.

The topographic setting implies the river has continually moved northwards, so that at present it flows closer to the Solsbury Hill side of the valley. Consequently most of the river deposits lie to the south, around Meadow and Manor Farms. Here the geological maps differentiate three terraces : No. 3 covering the present area of Bathampton village from 38-42m O.D., a second from 23-30m O.D., and the lowest, to the north, between 22-19m O.D. i.e. down to the present day river (Fig. 4.1).
The use of marked slope changes to delimit the terraces is questionable, particularly in the light of the deposits encountered when trial pitting, during the present research. As discussed later, the topographic



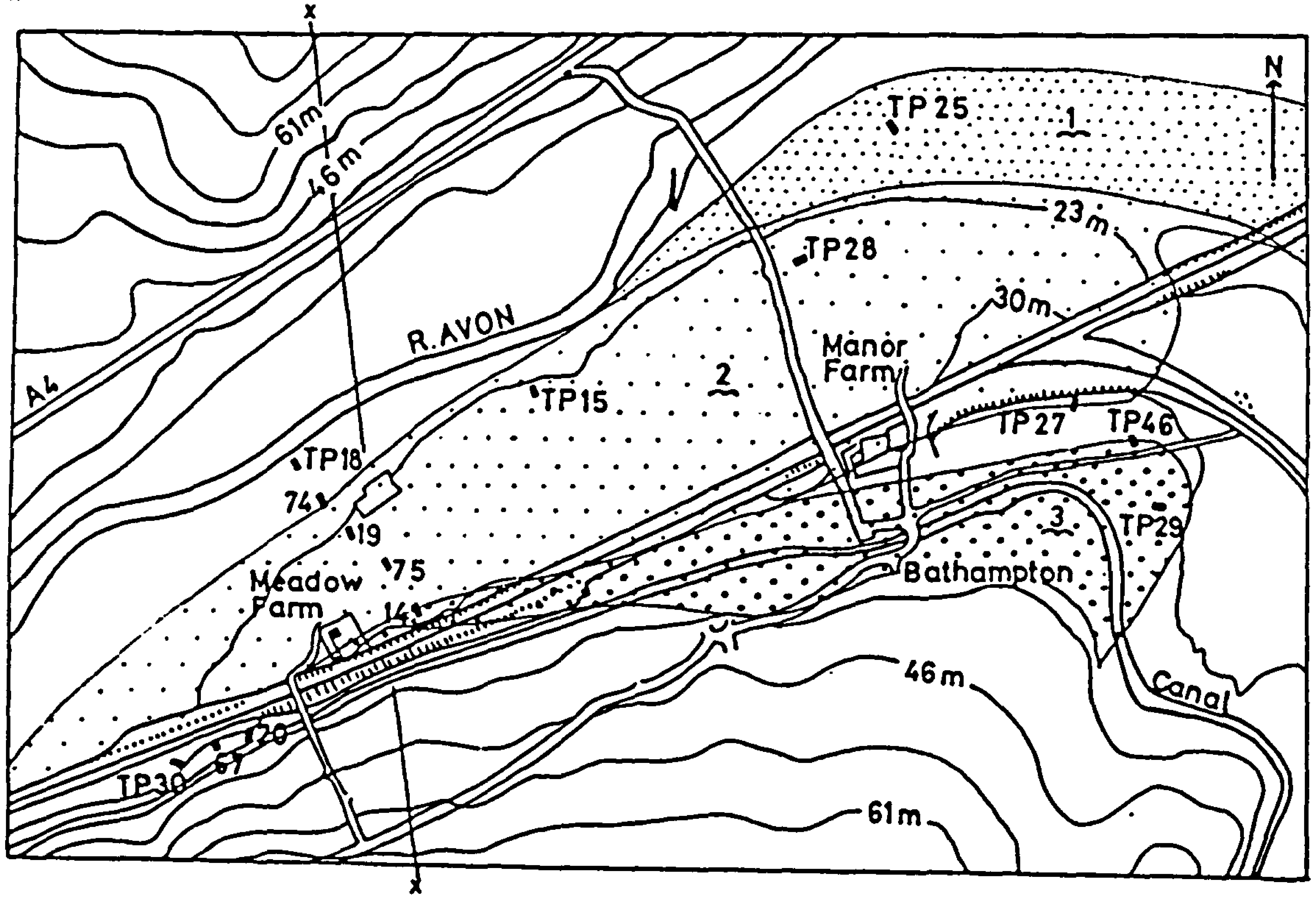


Figure 4.1 : Cross-section of the Avon Valley at Bathampton, the terrace deposits, and trial pit sites

0 200
metres

changes are more probably the toes of solifluction masses rather than erosional slopes between terraces (see Photo 4.1).

The present author's fieldwork and study of the old maps of the area revealed that the gravels around Bathampton were worked only on a small scale. This is surprising in view of the two railway lines running across the area. The maps record one pit, now infilled, on the site of the playing fields south of the canal. A second, larger pit is indicated at Manor Farm, where 1.5m of gravel was exposed at the time of the mapping. More extensive exploitation of the gravel may have been limited by the disturbed nature of some of the deposits, as shown below.

FIELDWORK RESULTS :

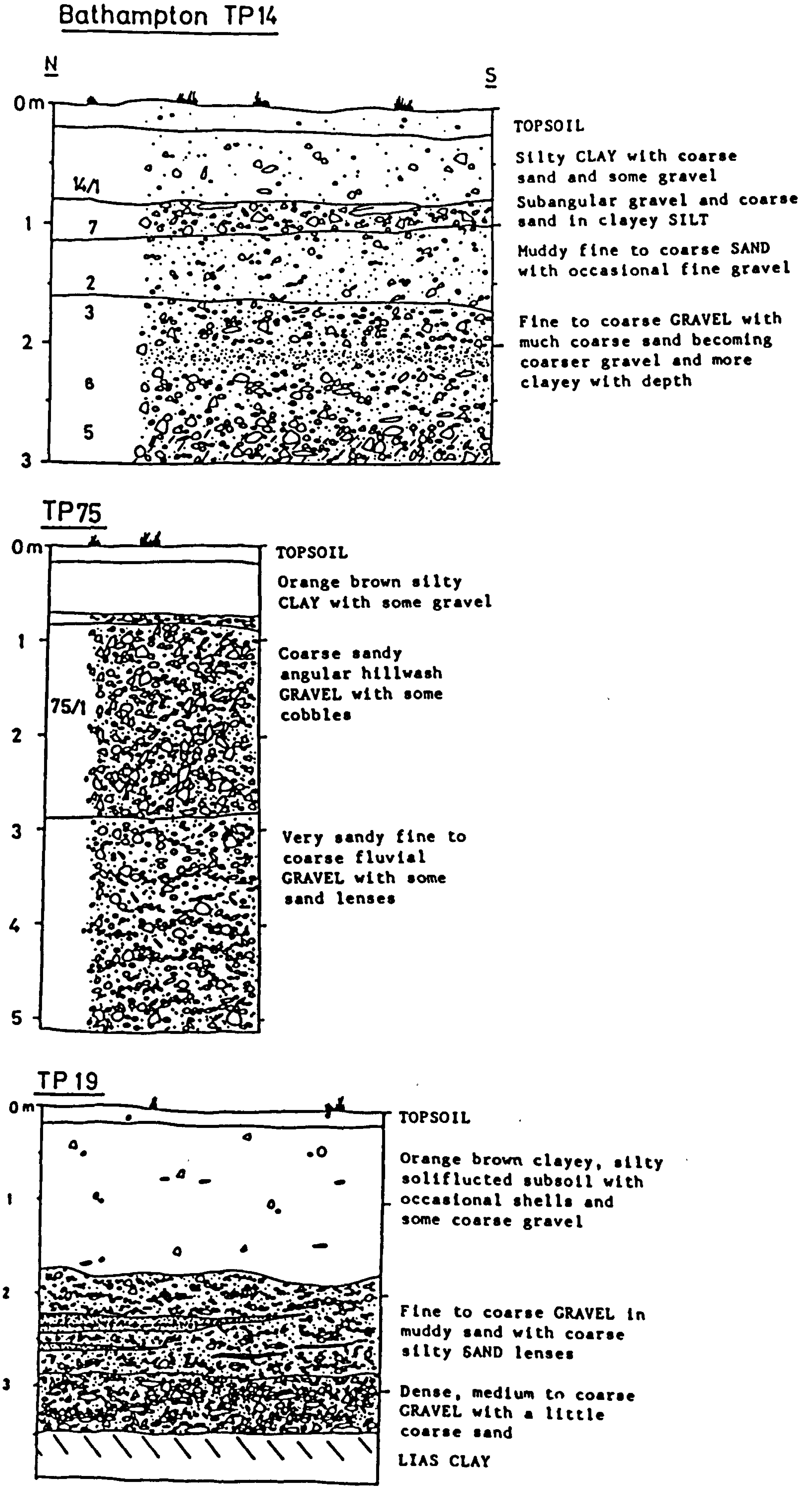
As no exposures of the terraces exist at present, in September 1982 two pits were dug at Meadow Farm to examine the nature of and sample the deposits, and to relate the subsurface geology to the present topography. In August 1983, further pitting by a site investigation company prior to the routing of the proposed Bath Bypass added to this information; the combined results are now presented.

Five of the trial pits were dug in a north-south line from the railway cutting, between Meadow Farm and the present river channel. This allowed the drawing of a cross section through the deposits (See Fig. 4.1 and 4.5).

TRIAL PIT 14 :-

Trial Pit 14 (TP14) was excavated at 29m O.D. (Fig. 4.2). The base did not reach bedrock, though from its relationship to the other data in Fig. 4.5 it was likely to be close to the solid geology. The lowest deposit seen was 1.4m of sandy gravel with discontinuous horizontal layering. The coarser basal portion has 11% mud, hence it is likely to be near the Lias Clay surface. Above this the main gravel is subrounded, fine to coarse, very poorly sorted and lacking in significant cohesive characteristics. A sandy lens running horizontally across the pit section

Figure 4.2 : Field descriptions of TP14, 75, 19, Bathampton



was recorded. The gravel consisted of mainly Jurassic limestones with other lithologies, including flint, chert and sandstone, totalling only a few percent. No structures were noted within the gravels exposed by the pit and the contact with the covering deposits is almost horizontal.

The covering deposit of this terrace material is 0.5-0.75m thick and consists of yellow, very poorly sorted sand, predominantly medium sized, but with some fine to medium gravel and a muddy matrix. The top surface of the deposit dips at 8^{o} northward, while the base is horizontal. This may represent a slope deposit, which has accumulated at the base of Bathampton Down.

The overlying deposit consists of 0.3m of subangular to angular fine to medium gravel in a matrix of coarse sandy clayey silt. Large limestone slabs occur at the upper surface. Compared with TP75 the deposit at this point is relatively thin.

Above this lies a further clayey silt with coarse sand and some fine to medium gravel. Shear planes were observed within the matrix of the deposit providing evidence of some movement.

Overlying the Pleistocene deposits is 0.2-0.3m of silty sandy topsoil.

Interpretation of the deposits in TP14 :

The lowest deposit seen in the pit is an excellent example of a fluvial terrace, consisting of predominantly local lithologies, transported sufficiently to achieve some rounding of the weak Jurassic limestone, yet not any great distance from their upstream source. The flint and chert lithologies suggest they are far travelled components, yet they are more likely to have been derived from the decalcified high level gravels on Bathampton Down, rather than transported directly from their parent outcrop.

The sandy material above this terrace gravel is suggestive of a movement deposit both from its sedimentological characteristics and its location.

Over this there is further evidence for a period of solifluction. Here the gravel is more angular and less sorted than the terrace gravel below. It is likely to have been formed by movement of frost shattered limestone fragments from higher up the hillside in a medium of saturated unstable fines. Such movement is reported to have occurred in periglacial environments when a period of warmer temperatures follows colder conditions. This leads to an excess of water due to the melting of ice lenses.

The next deposit consists of further, soliflucted clayey silt with coarse sand and fine to medium gravel. This change, with the proportion of gravel falling from 47% to some 10-15% may indicate a period of high precipitation and run-off but without the availability of frost shattered and weathered rock debris. Evidence of movement comes from observing shear planes within the matrix of the deposit.

This pit can thus be summarised as terrace material covered by a very sandy slope deposit, which is in turn followed by an angular hillwash. This gave way to finer soliflucted material.

TP75 :-

Trial Pit 75, dug as part of the bypass investigation, is about 60m to the north of TP14. The geology inspected again indicates a complex layering (Fig. 4.2). Although dug to 5m (from a surface at 25.3m O.D.), the base of the gravels was not reached. These gravels form the lower 2.1m and were made up of a series of discontinuous sand and gravel lenses, the pebbles being subrounded. The coarsening of the gravel and addition of more mud towards the junction with the Lias Clay (seen in those pits which reached bedrock) was not found here. The deposits may well be far greater in thickness, perhaps here being nearer to the position of the palaeochannel.

Above the fluvial sediments there is a horizontal contact with the overlying deposit. This consists of 2.2m of coarse sandy angular gravel and cobbles, much greater than the 0.3m seen in TP14. The top 0.10m formed a partially decalcified, recemented fine gravel surface and may be related to a weathered horizon. Above lies 0.7m of orange brown subsoil as in TP14, without an equivalent gravel component.

TP19 :-

Trial pit 19 (Fig. 4.2 and Photo 4.2) was dug 87m further north; here the bedrock was reached at 3.5m from the top surface at 23.5m O.D. This was the highest point on the cross-section (Fig. 4.5) at which the Lias Clay was observed. Above the Clay there was evidence for two units within the terrace gravels. From 2.9-3.5m the gravel was dense, of medium to coarse size, and with only a little coarse sand. Many of the limestone pebbles were very flattened and some up to 300mm in length. The second unit was 1.15m thick and resembled pits 14 and 75, being fine to coarse, loose and in a sandy, slightly muddy matrix. This pit showed good development of both coarse sandy and fine pebble lenses, the latter were stained dark brown. The uneven upper surface of these fluvial gravels was iron stained to a depth of 0.4m, and as such may again show a degree of weathering, occurring on the exposed top of the river terrace.

The same clayey, silty material as seen in TPs 14 and 75 occurs above the fluvial deposits. Here this cover is at its greatest thickness (1.55m). Again shear planes were noted as well as a small amount of fine, subrounded to angular gravel. Thus this pit differs from TPs 14 and 75 in not having a coarse gravel hillwash component. Perhaps the later solifluncted mud deposit has covered a greater area of the slope than the coarse gravel, which would require a greater energy to move it.

TP74 :-

A shallow pit was placed 50m further north at 20.1m O.D. (Fig. 4.5). This reached Lias Clay bedrock within 1m, with 0.7m of light brown alluvial silt and clay above.

TP18 :-

The most northerly pit of the cross-section (TP18) lay just 19m from the present day river bank, and sampled the most recent alluvial deposits (Fig. 4.3). The Lias Clay at 4.5m from the ground surface at 19.4m O.D. was covered by a deposit of fine to coarse gravel with a matrix of pale grey, sandy, clayey silt. This matrix is probably derived from the Lias Clay.

Over the gravel lies 3.6m of alluvial silts and clays. The shell material which was found within the muds provides evidence of a transient floodplain environment.

The shells were sampled from Layers 2 (1.2m of orange yellow silty clay), Layer 3 (0.6m of yellow brown sandy, very silty clay), and Layer 4 (0.3m of pale grey silty clay). After washing and sieving, the shells were identified by Dr. D. Gilbertson. The environmental conditions suggested by the various taxa confirm a Flandrian floodplain accumulation. A full list of the species is contained in Appendix II.

Layer 4 above the primary peaty silts and clays produced three habitat groups :

a) woodland/shaded ground (Clausiliidae, Zonitidae)
b) marsh/wet ground subject to flooding and desiccation (Anisus leucostoma)
c) aquatic environments (Pisidium spp., Planorbis spp.)

However, the fauna was very limited in numbers suggesting infrequent flooding only and rapid destruction of those shells that were deposited. The date indicated is post Early Flandrian.

Layer 3, above this, produced a larger sample with the same three faunal components, suggestive of a woodland floodplain (Discus rotundus), by a quiet flowing river (Valvata piscinalis). Again the date is post Early Flandrian.

Layer 2 contains the largest number of species, accumulating on a wetter floodplain with more trees or shrubs. These were the youngest of the shells examined, giving a post Early-Mid Flandrian date.

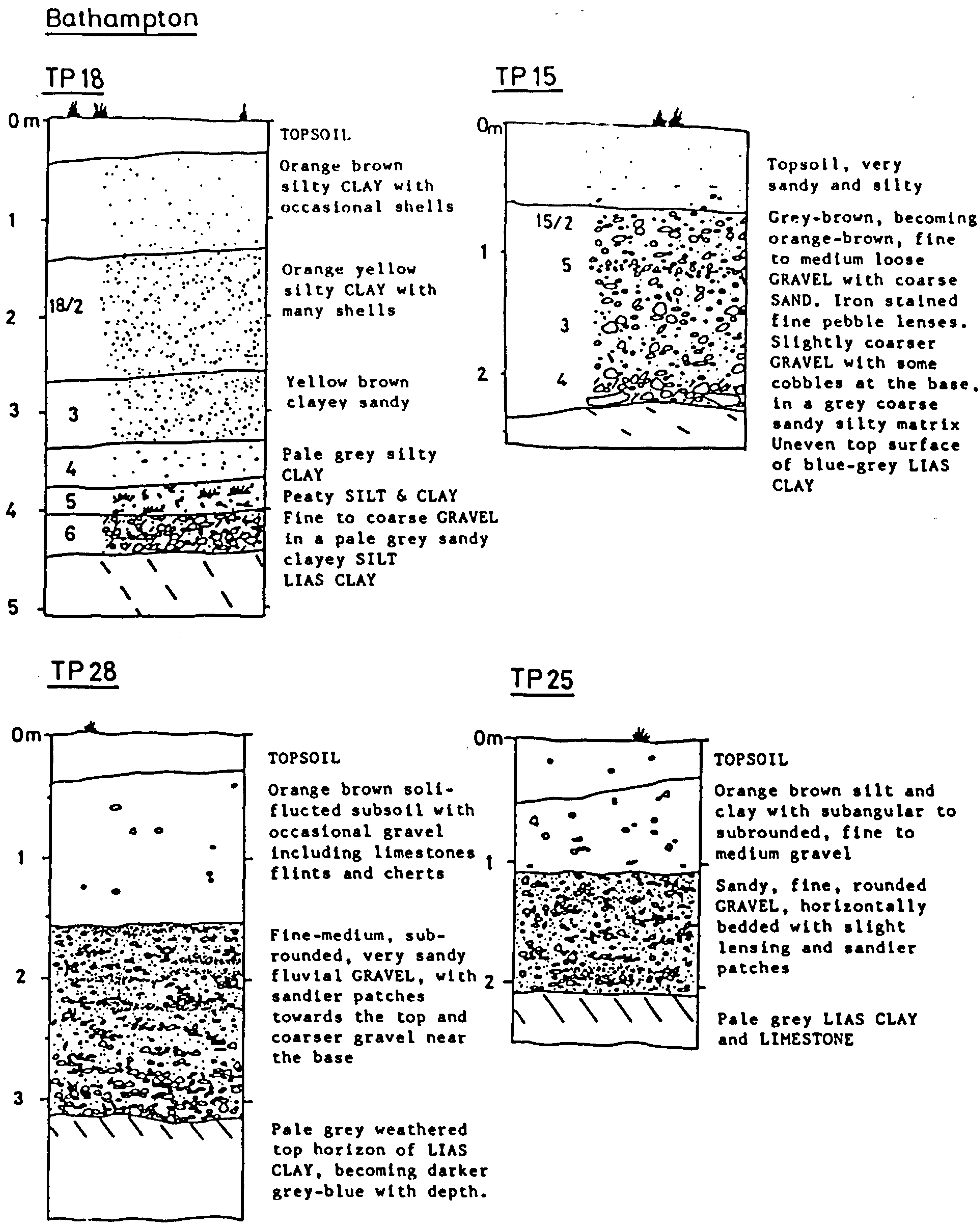


Figure 4.3 : Field descriptions of Bathampton TPs 18, 15, 28, 25

TP15 :-

Another pit (TP15), dug in 1982, to the northeast of the line of five pits, was on the edge of the topographic terrace at 23m O.D., about the same level as TP19 (Fig. 4.3 and Photo 4.3). The Lias Clay had an uneven upper surface at 2.2-2.6m. Above the Clay was 1.6-2.0m of classic terrace gravel. At its base this had the typical 0.2-0.3m of slightly coarser gravel with some cobbles in a grey sandy, silty matrix, graduating into a very mixed, fine to medium gravel with sand. An ironstained pebble band formed a continuous horizon across the deposit. Above the gravel was 0.1-0.2m of very sandy, silty topsoil.

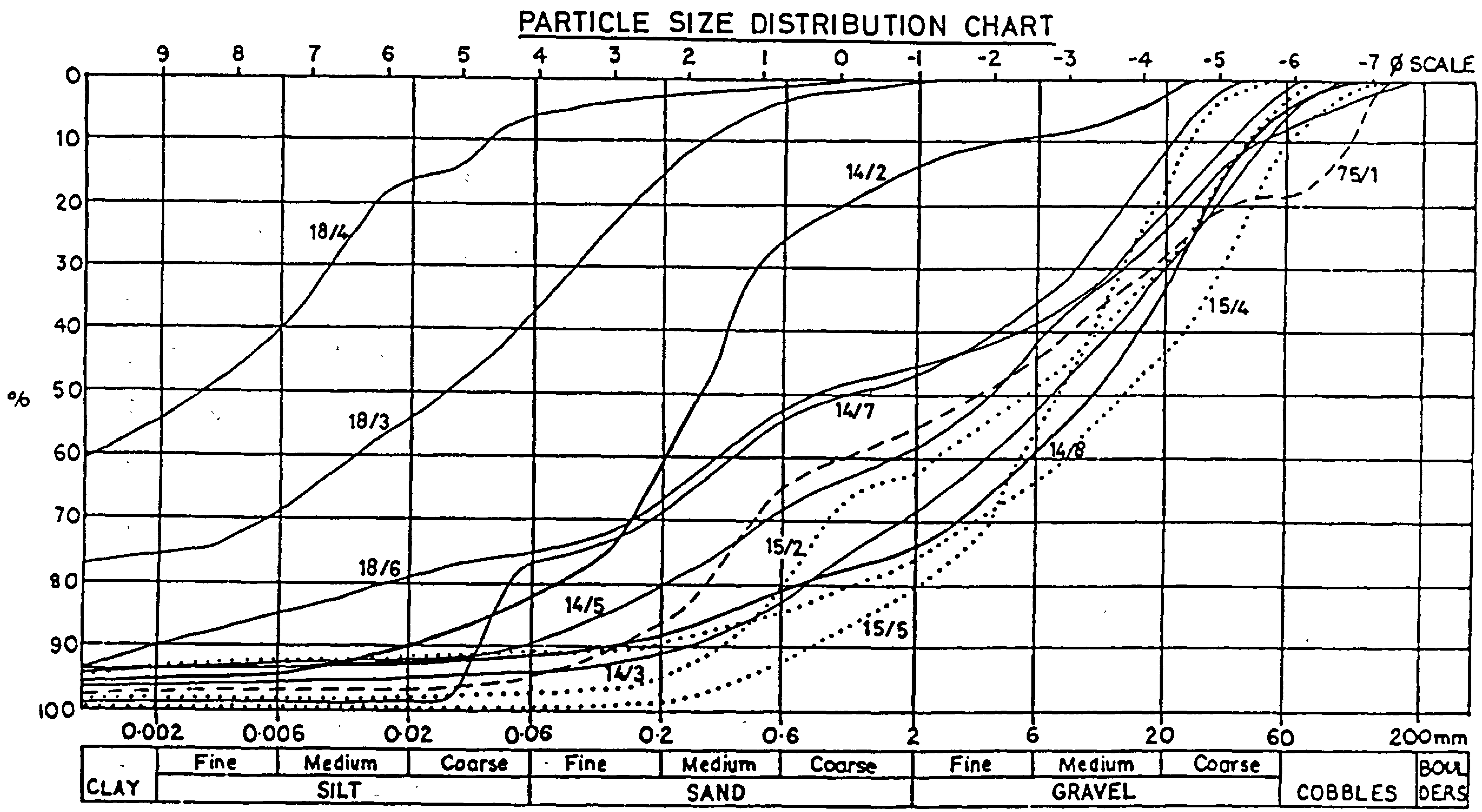
Particle Size Results :

Fig. 4.4 shows particle size distribution curves of the samples taken at Meadow Farm. The Recent alluvial silts and clays (samples 18/3 and 18/4) contrast with the coarse lag gravel (18/6); the unusually high percentage of fines in such a deposit is likely to be related to downward percolating waters containing large amounts of fine sediments, probably derived from the Lias Clay (on appearance).

The main fluvial gravel samples all gave very similar particle size curves (samples 14/3,5,8, and 15/2,4,5) with less than 10% mud, less than 10% cobbles and between 50 to 80% gravel. In contrast, the angular hillwash of TP75/1 shows nearly 20% cobbles, 37% gravel, and 50% sand. Again sample 14/7 is similar. Solifluction material, predominantly sandy with only 14% gravel and 18% mud is indicated in Sample 14/2.

TPs 30, 67 and 20 :-

Southwest of the pits at Meadow Farm, three more pits were dug between the railway line and the Kennet and Avon Canal (TP30, 67 and 20 at 28.3m, 32m, and 31.5m O.D. respectively) (Fig. 4.1). These were dug to appraise the lower hillslope and hillwash deposits north of Bathampton Down (Fig. 4.5).



BATHAMPTON: Trial pits 14,18,75,15

Figure 4.4

TP30 :-

Undisturbed fluvial terrace material was found below 22.2m O.D. in TP30 only, while above this were similar deposits to those encountered in TPs 14 and 75, though in varying configurations. A structureless very gravelly clayey silt, similar in thickness to TP14, cut across and through the top of the terrace gravels. This was succeeded in turn by 3.5m of clayey sandy, angular gravel. This closely resembles that in TP14 though the dip (obtained from the stratification) was $5^{\circ}/305^{\circ}$ in TP30 (and $20^{\circ}/320^{\circ}$ in TP67). The uppermost deposit consists of more grey and yellow sandy clay.

TP67 :-

In TP67 this sequence was repeated with the angular gravel continuing to below 24.2m O.D. and obviously disturbed by the downslope movement of a mass of Lias Clay.

TP20 :-

In TP20, disturbed Lias Clay was again recorded at the base of the pit, above which is a very gravelly, sandy clay with lenses of sandy, clayey, angular gravel. 0.6m of clays and sands have been deposited over the coarser gravels and they in turn are truncated by the uppermost layers of steeply dipping, gravelly sandy clay as in the other pits.

Thus in these three pits, the deposits support the interpretation of the uppermost sequence in TPs 14, 75 and 19 being the result of movements. Here the landslip, hillwash and mudflow sequence dominates. This is in contrast to the basal sequence of the pits on the lower slopes, where fluvial material is predominant.

CROSS-SECTION (Fig. 4.5)

Fig. 4.5a is a cross-section through Meadow Farm, combining the logs from TPs 14, 75, 19, 74 and 18, plus the three southernmost pits 20, 67 and 30. Lias Clay bedrock is seen in situ in the lower three pits. While TP18 foudd a lag gravel and alluvium over the bedrock, TP74 showed only 0.7m of more recent material over the bedrock. The edge of the coarse fluvial terrace deposit thus lies south of TP74, achieving 1.75m depth of gravel in TP19. The toe of the upper silty soliflucted material again lies between TPs 19 and 74, while the angular hillwash gravel lenses out to the south, between TPs 75 and 19. No disturbed strata were noted in TP14, so that the limit of major landslipping falls between this and the southern group of pits 20, 67 and 30.

TPs ON MANOR FARM :

Fig. 4.5b shows a section through the pits positioned to the northeast on Manor Farm (TPs 25, 28, 27, 46, 29) (Fig. 4.1, for positions).

The lowest, TPs 25 and 28, sampled the two topographic terrace levels at 20.6m and 25.3m O.D. respectively (see Fig. 4.3). TP25 reached the Lias Clay at 2.1m and proved 1m of terrace gravels. The gravel was fine to medium, subrounded and horizontally bedded with some sandier lenses. Resting on the irregular gravel surface was 0.6-0.8m of silts and clays.

TP28 (like TPs 15 and 19) was placed on the "23m terrace" level, and like them gave 1.5m of typical fluvial gravels over Lias Clay at 3.1m. The uppermost deposit consisted of 1.2m of orange brown silts with occasional gravel, similar to those of TPs 14, 75 and 19.

In the area of this pit, what would at first look to be the edge of a terrace bench is markedly undulating in height and irregular in line. Using the evidence of the trial pits and borehole logs, it can now be interpreted as the front edge of a soliflucted mass.

Figure 4.5 : Cross-sections through the trial pits at Meadow and Manor Farms, Bathampton

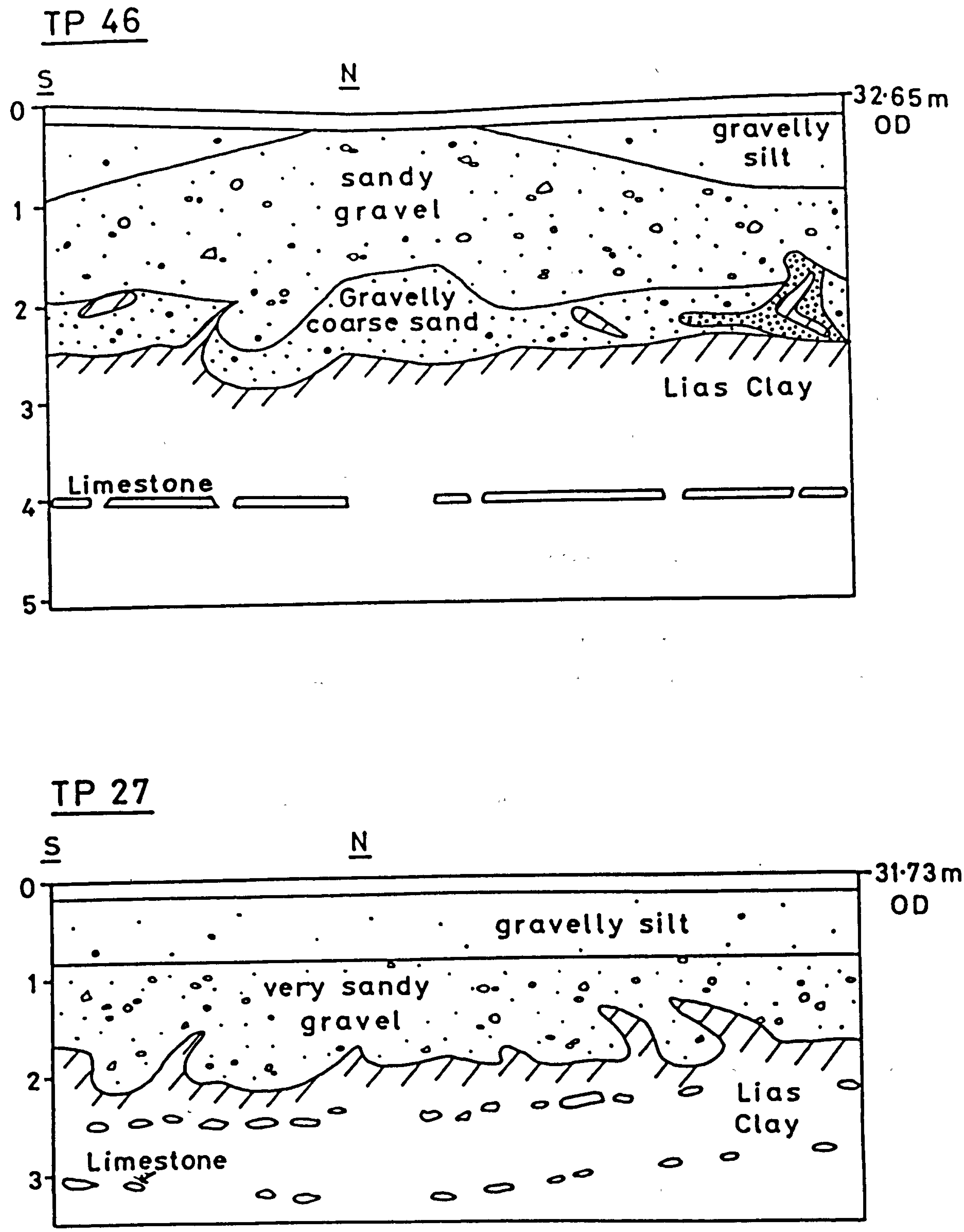


Figure 4.6 : Cryoturbated deposits in TPs 46 and 27, Bathampton

TP27; 46; 29 :-

Moving south of the railway, TP27 uncovered c. 1m of very sandy fluvial gravel beneath a gravelly, silty clay deposit (Fig. 4.6). Below was the Lias Clay, but here the bedrock had been injected upwards into the gravels in flame structures, due to cryoturbation processes. Similar features were encountered in TP46. However in this pit a gravelly coarse sand between the main gravel and the Lias Clay had also been deformed and fully enclosed wedges or lenses of the Lias were separated from the main bedrock. Pit 29, to the south, encountered only a thin layer of silty clay over the bedrock.

These deposits show further evidence of a period of cold climate causing deformation of the bedrock mudstone and fluvial gravels. This may well have been the cold phase which produced the angular weathering debris, transported downslope during an ameliorating episode and found in TPs 14 and 75.

Returning to the cross-section through this final set of pits (Fig. 4.5b), the Lias bedrock surface is seen to have a constant slope of c. 3° from south to north with c. 1m of fluvial gravel above.

SUMMARY :

Considering the information obtained from these trial pits at Bathampton, the following points emerge :

1) the slope changes seen on the ground surface are more related to the presence of solifluction masses rather than to either fluvial gravels or terrace levels.

2) the thickness, angle of rest, and content (see also Chap. 5) of the fluvial gravels are very similar across the lengths of the sections, so that no division of the gravels into distinct units is necessary.

Thus the argument for separate terrace gravels, as projected from topographic evidence, is weakened very considerably and instead the suggestion of a single gravel deposit is put forward.

The following depositional history of the Bathampton sequence is proposed :

8) Accretion of about 4m of alluvial silts and clays (to around 20m O.D.) as the River Avon built up its floodplain to equate with the Flandrian rise in sea level.

7) Late glacial deposition of basal gravels at around 15m O.D.

6) Glacial period (Devensian?) with a resulting low sea level, causing rejuvenation and the cutting of a new channel by the Avon.

5) Continued wet conditions causing solifluction movement of saturated and unstable gravelly silts, which covered the fluvial gravels and angular hillwash, down to a height of 20m O.D.

4) Climatic amelioration with high pore pressures developed in the clays causing landslipping on slopes above 30m O.D. On the lower slopes (e.g..at 24 and 29m O.D.) angular debris suggests hillwash movement.

3) A cold climatic episode, during which weathering caused rock debris to accumulate on the limestones of the upper slopes of Bathampton Down. Cryoturbation occurred in the Lias Clay and fluvial gravels of the floodplain.

2) River Avon flowing westwards and depositing gravel over the Lias Clay between 20 and 30m O.D. The main channel existed to the south of its present position and had a high capacity.

1) Lias Clay bedrock surface sloping at 3^{o} northwards.

2) THE CITY OF BATH

a) TWERTON

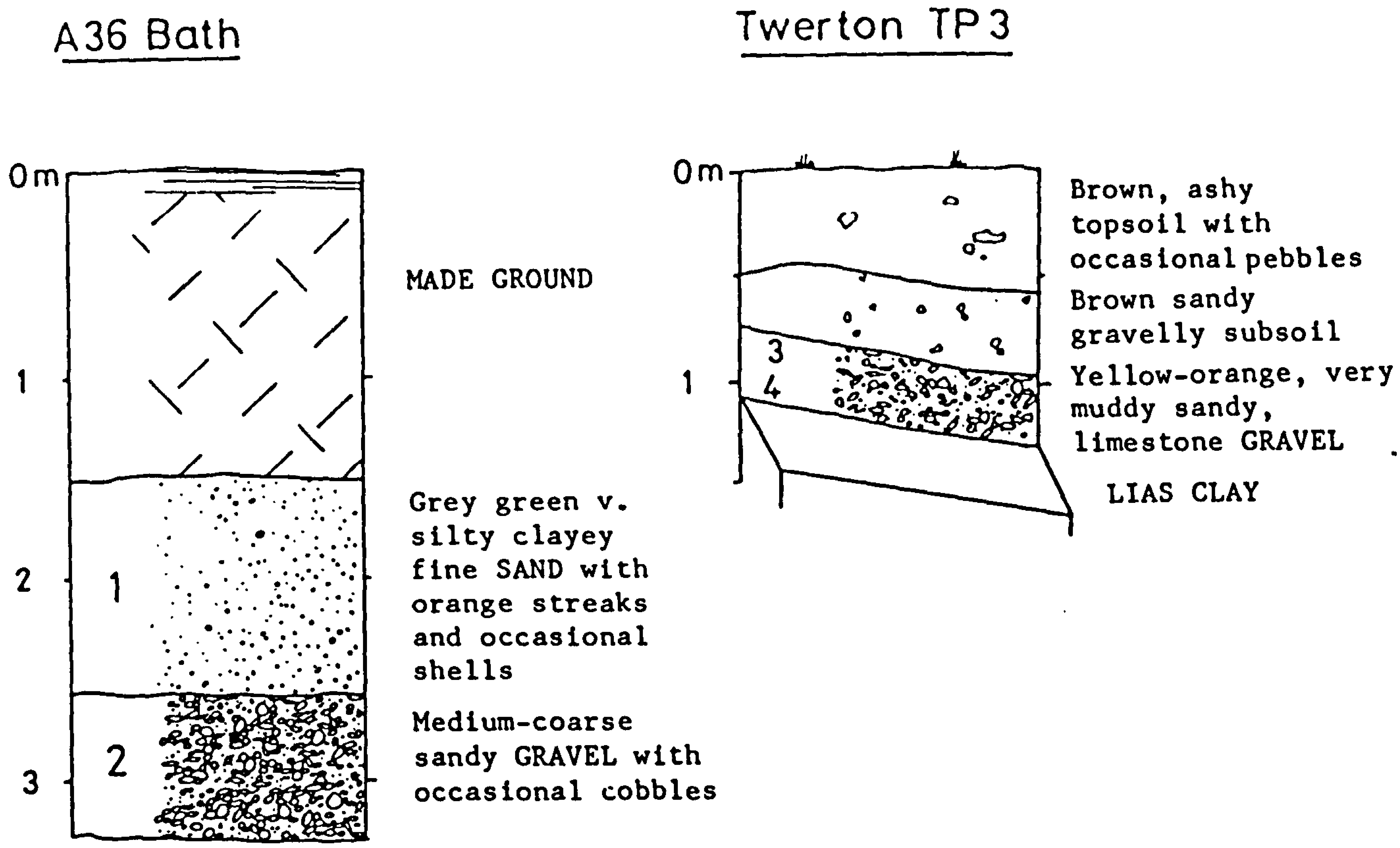
In view of the descriptions of these gravels in the literature (Chap. 2), it was considered necessary to attempt a reappraisal of the deposits. Unfortunately nowadays the Twerton area is a densely developed district of Bath, with the former gravel workings infilled. The Morefield Cutting (Chap. 2) has been converted by the City Council into a Linear Park for recreational use. Permission was obtained from the Parks Department to make a small excavation in the Cutting for the purpose of examining any remaining gravels. The area selected as most promising was around ST 735642, and the excavation (TP3) was made in the southern embankment, some 10m east of the Claude Avenue bridge, at 48.7m O.D. (Fig. 4.7 and Photo 4.4).

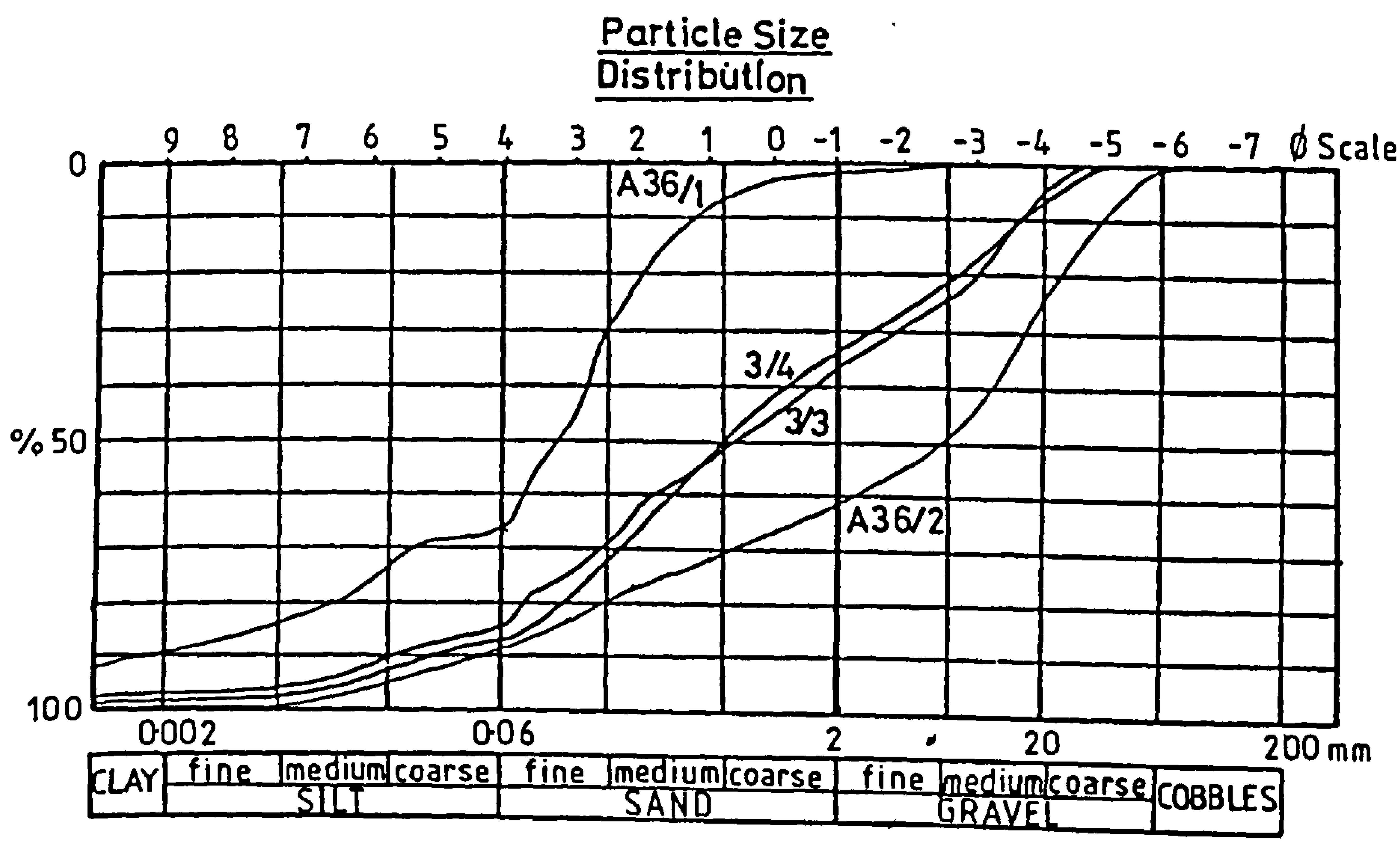
The face was excavated to expose a 1m wide vertical section through the deposits. The dark brown topsoil contained a large amount of ash and fill. Below 0.53m was a more sandy subsoil, light brown in colour and containing some medium gravel. The top surface of the main gravel deposit, which consisted of 0.34-0.38m of yellow orange, sandy, fine to medium gravel in a muddy matrix, was found at 0.75m. Below 1.1m was the slightly irregular surface of the light blue grey Lias Clay, dipping slightly to the northwest (Photo 4.4).

The main constituents of the gravel were noted to be of oolitic limestone whilst the overall yellow colour of the material is attributed to the Jurassic rock types, including for example the Midford Sand. As the largest pebble noted was only 60mm, and from the particle size results, the deposit is noted to have a finer grade than those recorded at Bathampton, the A36 trench and at Newton St. Loe.

b) BATH, A36 :

In the autumn of 1982, a sewerage pipeline trench was excavated across the A36 Warminster to Bristol road at ST 742647. Two short sections were recorded.





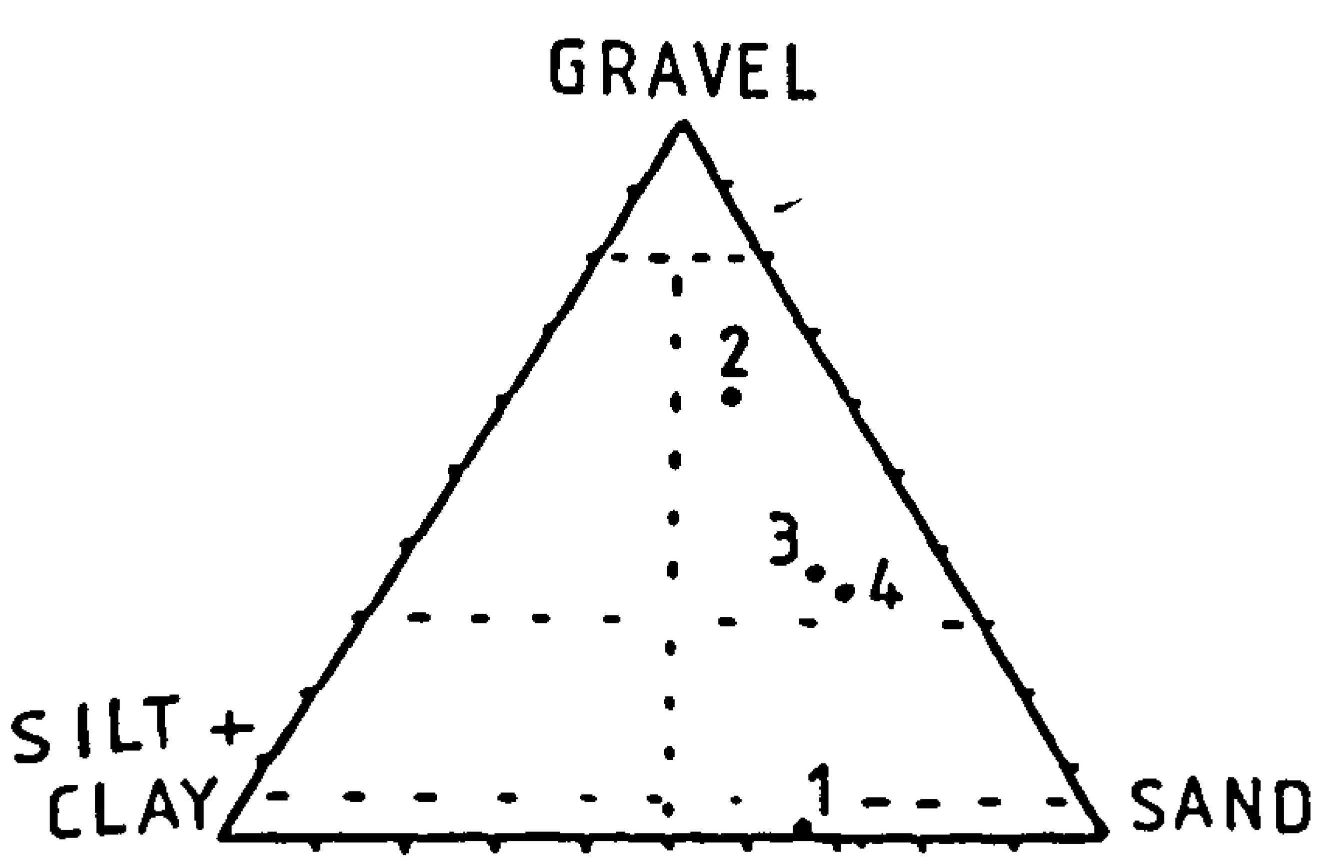


Figure 4.7 : Field descriptions and particle size results, A36, Bath, and TP3, Twerton

The maximum depth of excavation occurred around an inspection chamber where 3m of material was exposed (Fig. 4.7). Below 1.5m of made ground and fill was 1.1m of grey green muddy sand. This was predominantly fine sand, but with very occasional fine gravel size pebbles and some 10% clay fraction. Occasional iron stained patches were noted.

From 2.6m was a gravel layer which continued below the trench base. Analysis of this material (sample A36/2) indicated a medium to coarse gravel with occasional cobbles. The matrix, although dominantly sandy, included a small percentage of silt. As at Bathampton and Newton St. Loe, the gravel was predominantly of rounded Jurassic limestone pebbles.

The second trench, only 1.5m deep, showed 0.8m of made ground, over grey green alluvium (as in the first section) which continued below the base of the excavation.

3) NEWTON ST. LOE

In this area the valley is perhaps better known for the presence of Coal Measures strata than for its fluvial deposits. In the past, coal was worked from several pits, in the small inlier of Carboniferous rocks. To the north of the A4 and along the broad valley floor, are areas of fluvial sands and gravels, which are marked on the geological maps as either Head or alluvium (Fig. 4.8).

Around the junction of the A36 and A4 roads, gravels were worked formerly from pits north of the GWR line, while the railway cutting was recorded on the 1:10560 Geological maps as exposing Head material overlying the Keuper Marl. Photo 4.5 shows an exposure of terrace gravel, containing a prominent sand lens which contained clayey silt horizons at its base. This material was recorded in 1967 (Hawkins, pers. comm.).

To the west of this, and just north of the Globe Inn junction on the A4, topographic features resembling terraces can be distinguished (visibly not dissimilar to those at Bathampton). The most marked change of slope runs just north of the A4, parallel to the present day river course.

To investigate the relation between this terracing and the subsurface geology, a series of pits were dug in the autumn of 1982. These comprised TPs 4, 5, 6 in the fields north of the Globe Inn, and TPs 7 and 8 by the railway line,north of the Twerton Turnpike junction of the A4 and the A36,

TP4 (Fig. 4.9) :

TP4, at 17.82m O.D., proved ashy topsoil and modern fill material to 1.7m. Below this was 1.5m thick of alluvial very clayey silty sand, with some gravel, light brown near its top surface and becoming more red brown and sandier with depth. No plant or molluscan remains were recovered from this layer. At 3.2m the dark red Keuper Marl was reached.

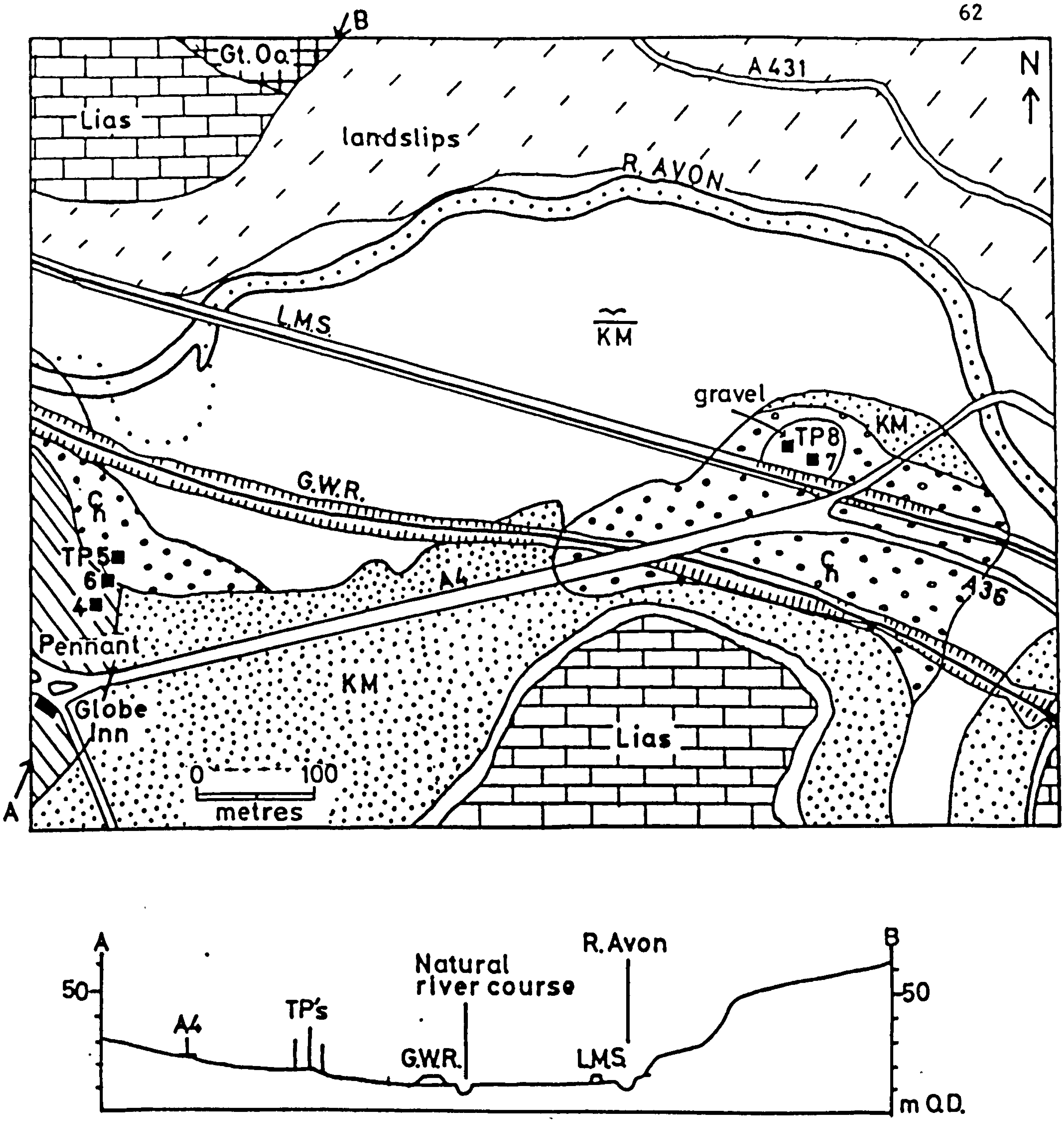


Figure 4.8 : Geology and trial pit sites at Newton St. Loe, Bath

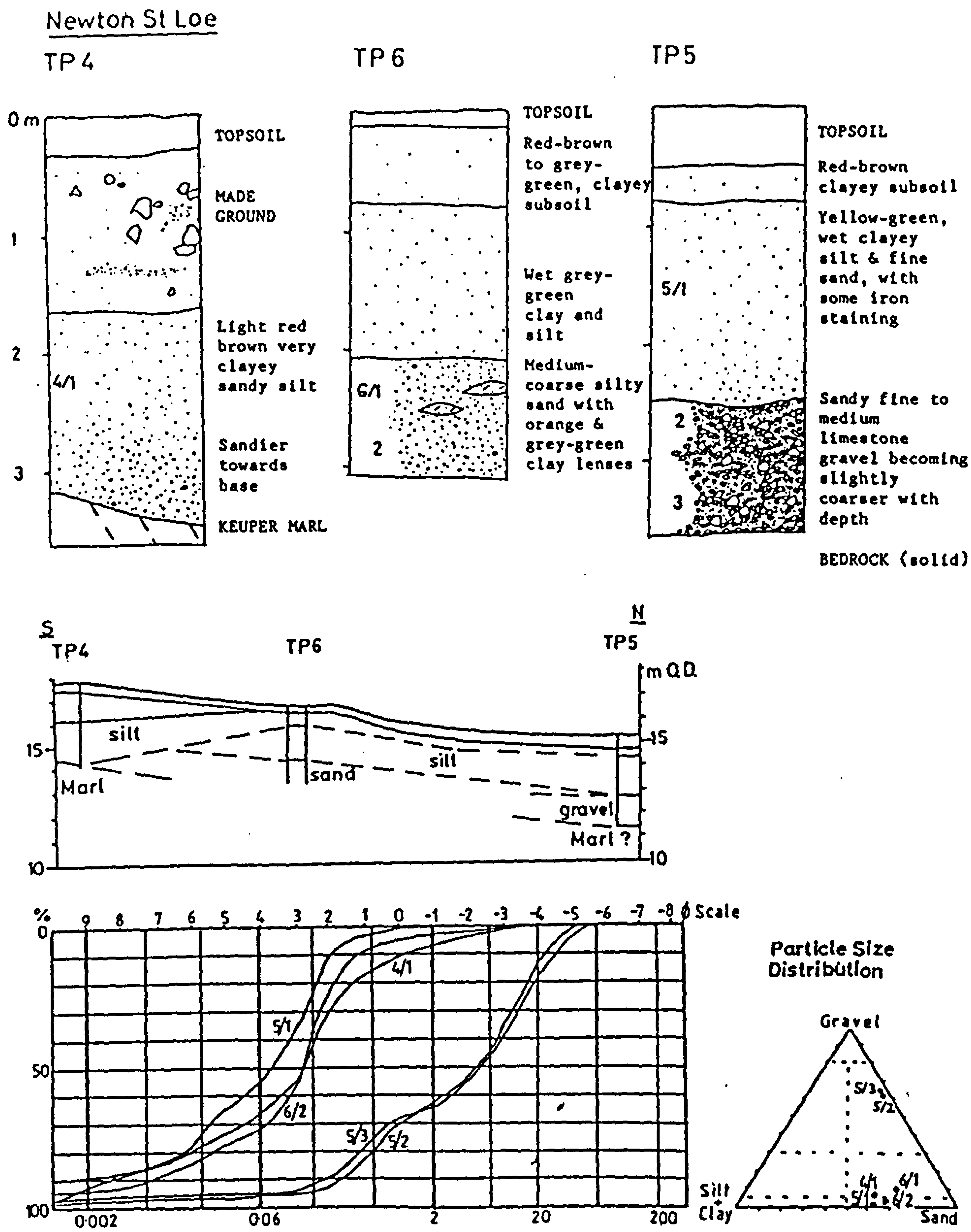


Figure 4.9 ; Field descriptions and particle size results, Newton St. Loe

TP6 (Fig. 4.9) :

This was dug 10m north of TP4, on the edge of the topographic feature at 16.6m O.D. Again the topsoil was an ashy, grey brown overlying red brown silty clayey subsoil to 0.7m. Beneath was 1.4m of wet, homogenous grey green silty clay, blanketing the underlying layer. At 2.1m the material had a greater proportion of sand in a muddy matrix. The pit was stopped at just below 3m because of side instability, with the sandy deposit continuing.

TP5 (Fig. 4.9) :

This was placed at the foot of the topographic terrace at 15.27m O.D. and again showed a fining upwards within the alluvium. Below the red brown subsoil was 1.7m of yellow green, very sandy mud, with occasional orange stained patches (Sample 5/1).

The water table was reached at 2.4m, which coincided with the top of a layer of very sandy fine to medium gravel, consisting mainly of rounded Jurassic limestone pebbles. Detailed examination of the deposit was impossible due to the water issuing from the extremely loose gravel. The pit was stopped at 3.7m, when the excavator hit solid bedrock, either the Pennant Sandstone, or a more lithified bed within the Keuper Marl. TP5, with 1.3m of fluvial gravel, was the only one of the three to find river deposits of coarser than sand grade.

TPs 7 and 8 :

In the second set of pits, at Twerton Turnpike, a slightly different sequence emerged. Here, both trial pits, just north of the old railway line, are at 22m O.D. The eastern one, TP7, showed disturbed strata, with spoil from the excavation of the railway line overlying the insitu deposits. The bedrock of dark red Keuper Marl at 2.2m was overlain by 0.4 to 0.55m of yellow sandy, clayey, fine to medium gravel. It appeared to fine upwards slightly, forming a sandier top portion, where the finer material is concentrated into indistinct horizontal lenses.

Above the sloping surface of this insitu gravel, was a lens of disturbed Keuper Marl, 0.4m thick, which contained some small pockets of gravel and subsoil. This material is likely to be overspill from the digging of the railway cutting just 25m to the south.

TP8 :

This was excavated 20m further to the northwest of TP7 to establish more clearly the nature of the gravels. Here again, a dark brown topsoil was found over a more orange brown sandy subsoil. Between 0.7-1m occurred some large Jurassic limestone slabs, which could easily have been moved into this position by solifluction. An orange brown slightly clayey sand layer separated these slabs from the main gravel below.

1.3m of gravels were encountered from 1.9m. These were similar to those in TP7 in both colour and content. It was noted that the thin sand layer above this may represent a fining upwards, related to a decrease in flow velocity. The Marl bedrock was encountered at 3.2m.

Summary :

Two terrace gravel deposits were differentiated at Newton St. Loe. The higher, seen in TPs 7 and 8 at Newbridge, is shown on the BGS Map as a small area of gravel over Head material. It is very probable that the same deposit extends southwards at least as far as the road junction of the A4/A36, where Photo 4.5 shows it exposed at about 24m O.D. It drops to 19-20m O.D. in the area of TPs 7 and 8.

The lower terrace gravel lies at 11.5-13m O.D., below a distinct topographic slope to the south of TP5. This feature, here at around 17m O.D., is seen again, to the north of TPs 7 and 8, at around 15m O.D.

There is therefore evidence of an upper terrace gravel horizon, which rests on a bench feature, with a second gravel deposit below this.

4. THE KEYNSHAM AREA

a) STIDHAM FARM :

Stidham Farm lies to the south of the River Avon, on the plateau above a bluff cut by the river, between Keynsham and Saltford (Fig. 4.10). This is one of the few areas in the river valley where commercial exploitation of the gravel deposits would be feasible, though this has been opposed on environmental grounds.

The site has been known for its gravel deposits for many years but other than brief mentions of the site in the literature (e.g. Woodward, 1876), the only detailed reference is in Davies and Fry (1929). At 21.3m O.D. they noted 1.8m of gravel. This consisted mainly of Jurassic limestone but including also some Carboniferous Limestone, Pennant and Quartzitic Sandstones, flint and chert, set in a quartz sand matrix. The base of this gravel is iron stained and below it is 0.3m of large, angular local limestone blocks, in a clay matrix. The whole deposit rests upon Lias Clay bedrock.

The former gravel pits are between 15-23m O.D. and exposed 1-2m of deposits. These have now been infilled and the farm today is predominantly arable.

In 1981 the landowner dug a trench with a mechanical excavator to the east of the farmhouse, to obtain gravel for farm tracks. The trench measured 4m wide by 50m long and up to 1.8m of gravel was removed. It was extended eastwards in 1982, with a further 7.5m x 70m being dug out (Photo 4.6). These two sites are named in this thesis Stidham A and Stidham C respectively. Stidham B was a small drainage trench dug near the farm entrance in 1981, only 0.75m deep, which penetrated alluvial type deposits.

The deposits are known to extend west almost as far as Keynsham, and while the major part of the present fieldwork was concentrated at Stidham, a further trial pit (TP9) was dug in 1982 to further assess the allvuial clays and the peripheral gravels.

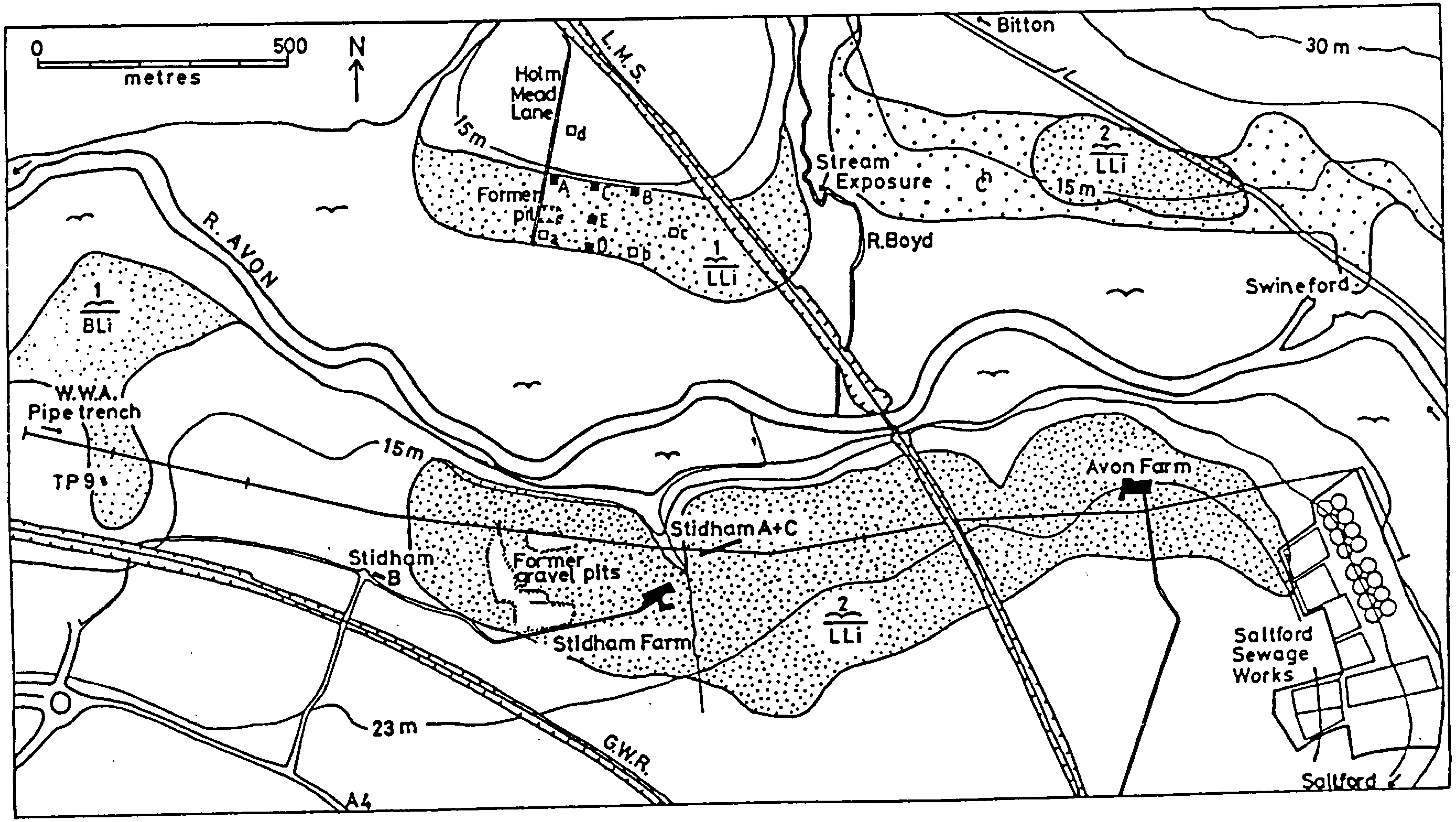


Figure 4.10 :

Geology and fieldwork sites at Stidham Farm and Bitton, near Keynsham

Further information was gained from a study of pipeline laying records made in 1980, when a trench had been dug by the Wessex Water Authority from Saltford Sewage works westwards across Avon and Stidham Farms, to Keynsham sewage works (Cross-section, Fig. 4.11).

In addition to those at Stidham Farm, further gravels are exposed in a stream bank section on the River Boyd, a tributary joining the Avon, to the northeast of Stidham (Fig. 4.10).

The WWA Pipeline (Fig. 4.11) :

In this trench, the gravels were first recorded over Lias Clay bedrock at around 20m O.D., on the edge of the Plateau surrounding Avon Farm. They are capped by silty, loamy topsoils westwards to Stidham Farm. In the area of Stidham pits A and C, the upper surface of the Lias falls to 18.5m O.D. while the ground level continues to dip very gently at 2^{o} to the west. In this locality the gravels are at their maximum recorded thickness of 3.5m. West of a small stream valley, in the area of the former pits, the gravels thin to less than 2m, above the bedrock at 19m O.D. (presumably partly removed by the diggings).

Continuing west, the rock head falls to 12m O.D. In this area the gravel increases to 2.5m thick and has up to 1m of silty loam deposited above it. Around the area of TP9, the ground elevation falls to 11-12m O.D. so that the near horizontal Lias surface lies within a few centimetres of the ground level.

In these pipe trench records the deposits are described simply as silty loam, over gravel with fines, above stiff clay bedrock with occasional limestone bands. Although this information was very valuable in allowing sections to be drawn, the proximity of the pipeline route to Stidham Pits A and C allowed a correlation between these engineering descriptions and the more detailed study made in the present work.

Figure 4.11 : Gravel deposits encountered in Wessex Water Authority trench from Saltford to Keynsham Sewage Works

Stratigraphy of Pits A and C :

The whole south face of Stidham A, and four specific areas of interest in Stidham C, were drawn at a scale of 1:20. The drawn sections (at natural scale) are reproduced in Figs. 4.12, 4.13, and 4.14. In Stidham A measurements were taken from the west end as shown, while in Pit C, work concentrated on the east end and hence the chainage zero was at the eastern extremity. Some 100 photos and 48 samples were taken.

When numbering the layers of the various deposits encountered during fieldwork the normal geological convention of numbering upwards was observed, i.e. the basal unit is Layer 1. At Stidham Farm however this was not realistic because of the nature of the exposure and so the layers were numbered downwards, i.e. the uppermost unit, the topsoil, was numbered 1. In Pit A the sections were recorded and sampled over a period of two weeks in June 1981. On the first visit to the site the Pit had been excavated for around one week and the level of the water table left only the upper layers visible. As recording progressed the water table dropped, so revealing the lower layers of gravels. Hence during study and sampling the units were numbered downwards to allow for the addition of new layers. Due to the large numbers of samples taken this convention has been continued throughout the subsequent sample analysis and study. The same Layer numbers were used when Stidham Pit C was recorded the following summer.

A similar stratigraphy is found along the length of the trenches and resembles that described by Davies and Fry in their examination of the former gravel pits.

The succession is as follows, numbered downwards (Photo 4.7) :

Layer 1. Medium brown topsoil
2. Orange brown disturbed sandy gravel
3. Intermittent coarse sand lens
4. Grey sandy gravel , stratified and in channel sequences
5-7. Orange brown unstratified gravel and sandy gravel
8-8a. Grey, muddy, sandy gravel
9. Cobbles and some coarse gravel in grey silty clay
10. Stiff blue grey Lias Clay

Figure 4.12 :

Gravel deposits exposed in Stidham Pit A

Figure 4.13 : Gravel deposits exposed in Stidham Pit C, Areas 1, 2 and 4

Figure 4.14 : Gravel deposits exposed in Stidham Pit C, Area 3

Layer 10 :

Only in Pit C, Area 3, was Lias Clay bedrock reached, with its surface apparently dipping very gently to the west (Photo 4.8). Although not recorded in the rest of the pit, the Lias Clay is likely to be near the base of the excavation level at around 20m O.D.

Layer 9 :

In Pit A, between 10-30m from the west, the lowest deposit exposed consisted of up to 0.3m of large, angular to subrounded blocks and slabs, mainly of Liassic Limestone. These were set in a grey clayey matrix, which in some cases also contained some coarse gravel (Photo 4.9). The Limestones were consistent in character and their large size made it impracticable to sample more than the matrix. Since the deposit lay beneath the water level, it is likely that contamination of the matrix would have occurred. Since it is very similar to a highly weathered Lias Clay, it is likely not to be part of the terrace deposit.

Layer 8/8a :

In Pit A this layer comprised between 0.5-1.1m of fine to coarse gravel with some cobbles in a grey clayey sand. Layer 8 is extremely poorly sorted, with 5% cobbles and 23% silt and clay (Sample A 17). Layer 8a is the upper, slightly better sorted, sandier horizon, which thickens to the west (Sample A27). At the top surface of 8a occur occasional thin lenses of fine, rounded pebbles, characteristically stained black.

Generally there were no clear structures or laminations within these layers, but rather they formed a very mixed deposit. The upper surface of Layer 8/8a is undulatory and lies around a level of 20.25m O.D.

In Pit C, this basal deposit was not so clearly defined. In Area 3 where the Lias contact was observed, the basal layer was a better sorted gravel. In Area 2, below 20.2m O.D. there is a disturbed layer of orange yellow, muddy, coarse gravel and cobbles (up to 250mm in length, Sample C7 and Photo 4.10). This resembles the coarser eastern equivalent of 8/8a of

Pit A. However, a layer 0.1-0.2m thick, of grey sand and gravel, lies below Layer 8, from which Sample C6 was taken.

On the south side of the Pit, a large, well rounded boulder, 0.38 x 0.28 x 0.28m, was observed (Photo 4.11). Although this was not found in situ, but lay against the section face, it is likely that it was derived from about 20.3m O.D. and around 20m from the east end, since a large hollow existed in the section, in the lowest gravels. This boulder is of Quartzitic Sandstone. Whilst the cobbles consist of mainly Liassic Limestones, some of Carboniferous Limestone, Oolitic limestone, several Pennant and Quartzitic Sandstones and one of Greensand chert were also observed (Photo 4.12).

Layers 5-7 :

In Pit A the horizons above Layer 8/8a were numbered 5,6,7 and 5/7. At the west end layer 5 lay over 7 and the two were clearly distinguishable, whereas further to the east they merged to become one horizon. At one point, Layer 6 is intercalated between them.

Layer 7 :

Layer 7 is an orange, very poorly sorted, fine to medium gravel with sand and mud (Sample A15).

Layer 6 :

Layer 6 is a small lens found at the far west end, very similar to 5 above, except for its grey colour (Samples A12 and A16).

Layer 5 :

Layer 5 consisted of 0.4m thick of orange, subangular, very poorly sorted sandy gravel (including 7% cobbles and 7% mud, Sample A4). Its bright colour comes from the iron rich mud matrix. This is presumed to be the heavily iron stained level noted by Davies and Fry (Photo 4.7). It can be distinguished from Layer 7 below by containing more coarse gravel, some cobbles and more fines, thus being a slightly less sorted deposit.

Layer 5/7 :

Layer 5 lenses out 10m from the west end of Pit A, while Layer 7 continues until 15m. West of 23m, the two units cannot be differentiated in a deposit of orange, sandy and muddy gravel, with thin, fine pebble lenses, some of which show a slight fining upwards. This deposit was equated with Layer 5/7 (Samples A22 and A26).

To the west the deposit becomes finer and more sandy, though always distinguishable from the Layers above by its general lack of stratification, the bright orange colour, and by having slightly fewer rounded pebbles.

In Pit C, the equivalent horizon (Layer 5, Samples C8 and C11) is again a very poorly sorted, mixed, sandy and muddy coarse gravel. It is not however orange in colour, but remains grey from the Lias Clay content of the matrix. There are also occasional sandy or fine gravel lenses, as in Layer 5/7 of Pit A.

Thus in both Pits A and C, above the coarse basal deposits (Layers 8/8a) Layers 5,6,7 and 5/7 are of a finer grade, though with occasional coarse gravel and cobbles. They are largely unstratified, the only structures within the gravels being small coarse sand or fine gravel lenses.

Layer 4 :

Layer 4 consisted of grey, stratified, sandy medium gravel between 0.25-0.75m thick. This occurs mainly as a channel fill deposit, the clearest example, from 37m westwards in Pit A. This particular channel deposit included two sand lenses, 0.2m thick and a succession of fine gravel lenses, within a predominantly platy limestone gravel, with the flat pebble surfaces almost horizontal. A similar channel fill was found in Pit C, Area 4 (Photo 4.13). This channel sequence covers the uneven top surfaces of the lower layers and has itself a more or less even upper surface, sloping from 21.4m O.D. at the east end, to 20.75m O.D. at the west.

Layer 4 is distinguished from Layers 5-7 by having :

a) a slightly finer mean grain size (See PSD graph, Fig. 4.15).
b) an absence of cobble size material, and less than 5% silt and clay, making the deposit relatively better sorted.
c) pebbles of platy Jurassic limestone, deposited horizontally.
d) a greater number of distinct, moderately sorted, fine gravel and sand lenses (Photo 4.14).

Layer 3 :

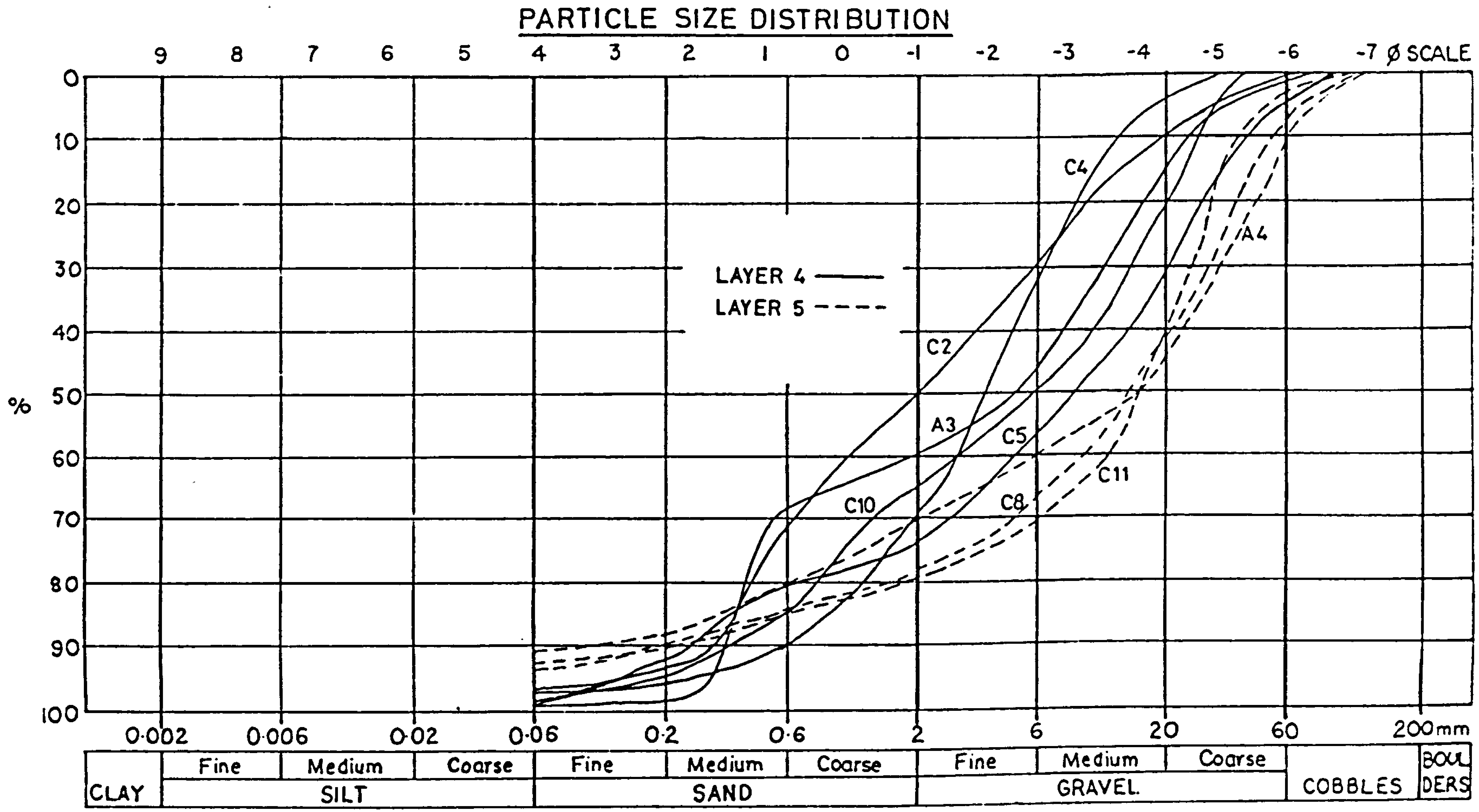
At the top of Layer 4, an intermittent coarse sand lens was noted (Layer 3, Photos 4.7 and 4.15, Samples A1 and A24). This was up to 0.2m thick, but generally less than 0.1m. It was unstratified as a whole, but in parts showed slight iron staining parallel to possible depositional horizons. In one place a rippled surface was observed, with deposition of a slightly finer, grey white sand in the intervening troughs.

Layer 2 :

Above Layer 3, or resting directly on Layer 4 where the sand lens (3) was absent, was the highest gravel horizon, Layer 2. This was an orange yellow, very poorly sorted, slightly silty, sandy gravel. It could be distinguished from Layer 4 below by being :

a) slightly coarser
b) by its colour
c) by having less distinct horizontal bedding.

The upper 0.1-0.2m of Layer 2 shows increasing incorporation of the soil horizons into the gravel, presumably due to ploughing and cultivation. In places the soil has penetrated to 0.4m below the ground surface, due to animal burrows (Pit A, 7m from the west), or by tree root disturbance.



Stidham: Layers 4,5

Figure 4.15 :

Particle size results, Layers 4 and 5, Stidham Farm

Post-depositional features :

1) Cryoturbation : two types of structure were noted :
i) involutions
ii) flame structures.

i) Involutions :

An example of cryoturbation was noted in Pit A, 23m from the west end, where the upper gravels were notably iron stained (Photo 4.16). Here platy limestone pebbles, lying horizontally on either side of the feature, were locally upturned to form a dome shaped feature, 0.3m wide at the base, 0.25m high and narrowing to 0.05m at the top. Such phenomena are described from unconsolidated deposits of periglacial climatic regions today.

It is notable that the example from Stidham occurs just above a 0.2m thick sand lens within Layer 4. The presence of a band of finer material may have made this area more susceptible to heave. With a higher ground water level in the past, differential porosity effects upon freezing and hence uplift may have been adequate to initiate some upturning.

Further examples of involutions were noted at 32m and 42m from the west end of the Pit.

ii) Flame Structures :

In Pit C, Area 3, between 16-20m, a set of flame structures was observed where the lower, coarse gravels (Layer 5) had been forced upwards into Layer 4 (Photo 4.17). The gently curving and rising features took the form of lenses, up to 1m in length. At one point the coarser pebbles of Layer 5 had pushed upwards by cryostatic pressure and had become completely separated from the main deposit and enclosed within the finer gravels as an S-shaped lens.

2) Colouration :

Several areas of iron staining were found at Stidham.

a) Layer 5, 6, 7, 5/7 : Already these entire layers have been noted as being of an orange-yellow colour, probably due to a higher iron content than the grey Layer 4 above. The orange yellow colouration was present within the silt and clay of the matrix but also had affected the gravel constituents themselves.

b) Several iron stained wedge-shaped areas were seen in Pit A, at 28m, 39m, and 45m. These could not be differentiated from the surrounding sediments in terms of clast size, type or orientation. Thus it is unlikely that they are the result of ice wedges such as are often reported in gravels of periglacial regions. They may be post-depositional features, resulting from percolation of iron rich water.

Another possible cause may have been disturbance by tree roots. This disturbance would account for the presence of the topsoil in the lower layers (e.g. as seen at 28m and 45m) and would also result in a variation of moisture content and aeration of the material around the roots. However there is no evidence for former field boundaries (and possibly trees) on the old Ordnance maps.

Interpretation of the deposits :

The trenches at Stidham Farm show the earlier deposits to be coarse, unsorted gravels giving way to finer better sorted materials. The environments of deposition suggested by these characteristics is a channel fill sequence of a braided river, with considerable but intermittent high energy flows.

Layer 9 consists of angular to subrounded blocks of Liassic Limestone. Their consistent lithology and setting, within grey blue silty clay, suggests they are the remains of a limestone band within the Lias Clay. The limestone has been exposed, weathered and disintegrated so that only these relic joint-bounded fragments now exist.

Layer 8/8a is interpreted as a coarse lag deposit, left as the river cut a new channel over the Lias Clay bedrock. The size of the included cobbles and boulders (such as the large Quartzitic sandstone block) and the mixed unstratified nature of the deposit suggests the energy must be equivalent to a fast flowing meltwater stream. The same type of deposition is seen in the stream bank section of the River Boyd.

Thus prior to the deposition of the main gravels at Stidham, there was a period of rapid flow carrying coarse gravels, cobbles and boulders, the products of intense local erosion. This is suggestive of a cold climatic episode followed by an amelioration. During the cold period much material was available for transport because of intense weathering in the presence of frost and ice on a largely unvegetated environment. The later amelioration, bringing about an increase in precipitation, run-off and stream discharge, supplied the energy required to remove these erosion products.

Over these basal deposits were Layers 5-7, with a slightly finer mean grain size. The lack of recognisable bedding within this mixed gravel is suggestive of a fast and erratic flow regime, with islands of largely unsorted gravel separating many small and constantly changing stream channels. This is the type of situation found in sandur plains close to glaciated regions, where meltwater is carried away from the ice margins. With distance from the ice or as the ice margin retreats on large scale melting, then the flow strength of the meltwater streams decreases. Thus a finer deposit results. This situation parallels that suggested by the deposits found in Layers 5-8 at Stidham.

Layer 4 records a change to a slightly better sorted deposit of finer mean grain size. The stream was still a braided one but with areas of quieter water causing the accumulation of sandier layers.

The gravels themselves were laid down in a more ordered fashion, with the flat limestone pebbles deposited with their maximum surface area parallel to the stream bed. No imbrication was recorded, however.

At the top of this layer, the coarse sand lens, Layer 3, shows that over a large part of this area, the flow decreased considerably, leaving a thick deposit of sand.

Thus the gravels are in a fining upwards sequence. This is interpreted as representing a gradual decrease in flow strength from the fast turbulent meltwater streams that deposited the boulder size material seen in Layer 8. Layers 3 and 4 are the result of a more regular flow with the formation of distinct bedding within the sands and gravels, and features such as rippled surfaces and parallel laminations being developed. Whereas Layers 5-7 are considered to be of a fluvioglacial nature, Layers 3 and 4 may record the change to a classic fluvial terrace deposit, with less water and a finer size of rock debris available for transport.

Layer 2 shows an increase in flow strength and irregularity again, reverting to deposition of sandy, coarse gravel with less distinct bedding.

Further evidence from this area of the floodplain was obtained at three locations :

b) TP9 dug on the periphery of the Stidham gravels
c) Stidham Pit B
d) the streambank exposure of the River Boyd, near Bitton
e) TPs A-E at Holm Mead Lane, Bitton.

b) TP9, Keynsham (Fig. 4.16) :

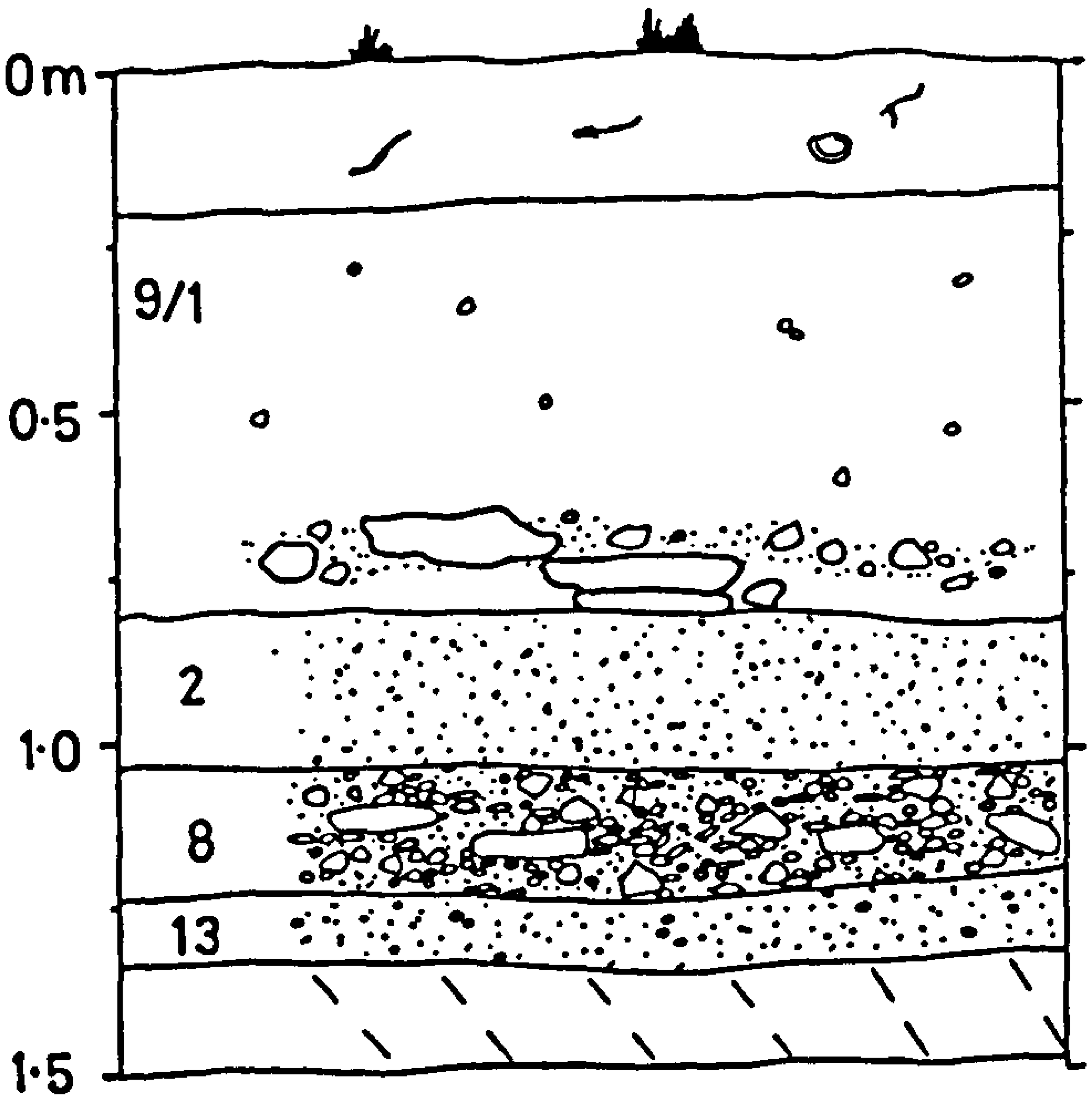
This hand dug pit was just to the south of the western end of the WWA trench, and was used to assess the location of the edges of the terrace gravels. On the 1:10560 Geological Sheet this area is marked as No. 1 terrace and is separated from the gravel deposits at Stidham Farm which are indicated as the No. 2 terrace. However, the WWA trench showed a continuous gravel horizon across the plateau, linking the two deposits (Fig. 4.10).

From the top surface of the pit at 13m O.D., Lias Clay was reached at 1.3m. Above was 0.2m of fine gravelly, muddy sand with patches of grey-green clay. This in turn was covered by 0.3-0.4m of extremely poorly sorted, sandy, muddy Jurassic limestone gravel, with occasional cobbles of flattened limestone and Greensand chert pebbles. This represented the only gravel sized material in the pit, and as such, the periphery of the fluvial terrace material (Photo 4.18).

Above this was 0.8m of alluvium in the form of a sandy mud, from which some shell material was obtained. The faunas suggested that the deposit was formed on the marshy floodplain of a stream or river with occasional nearby trees or shrubs. The material dates to younger than the very early Flandrian (see shell appendix No. II).

At 0.75m depth, within this Flandrian alluvium, was a thin layer (0.1m thick) of large cobbles of Jurassic limestone and Greensand chert, with some finer gravel in between. The origin of this is unclear, though it may be a man-made feature, perhaps connected with attempts to drain wet ground. Another possible origin of this material is one of deposition

Keynsham TP9



TOPSOIL

Grey-brown clayey SILT with occasional shells and fine gravel

Level of cobbles and some gravel of Jurassic limestone set within the grey clayey silt

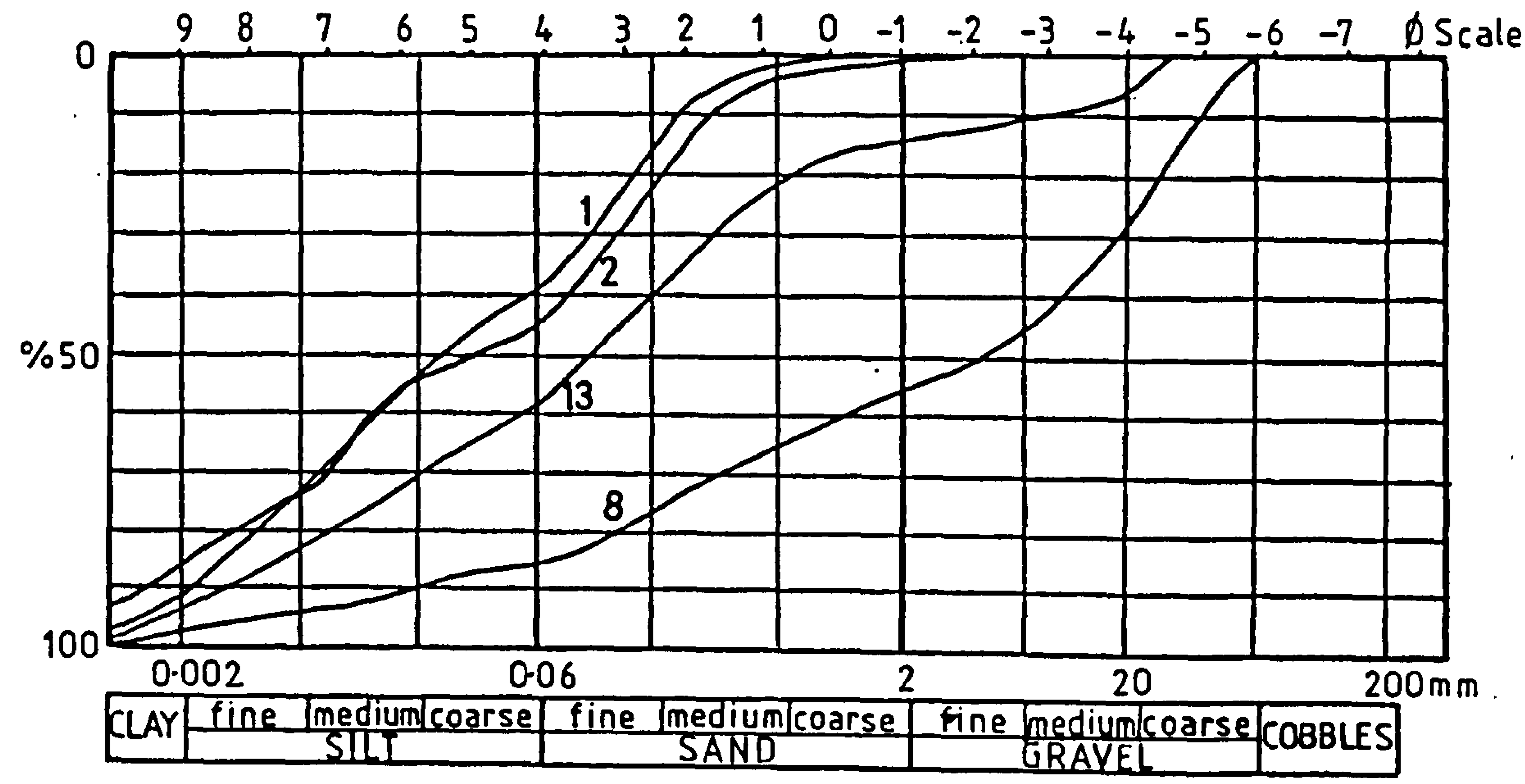
Grey green sandy CLAY with shells and some iron staining

Very sandy medium-coarse GRAVEL with flat limestone cobbles & cherts

Very silty SAND with gravel and grey green clay

Blue grey LIAS CLAY

Particle Size Distribution



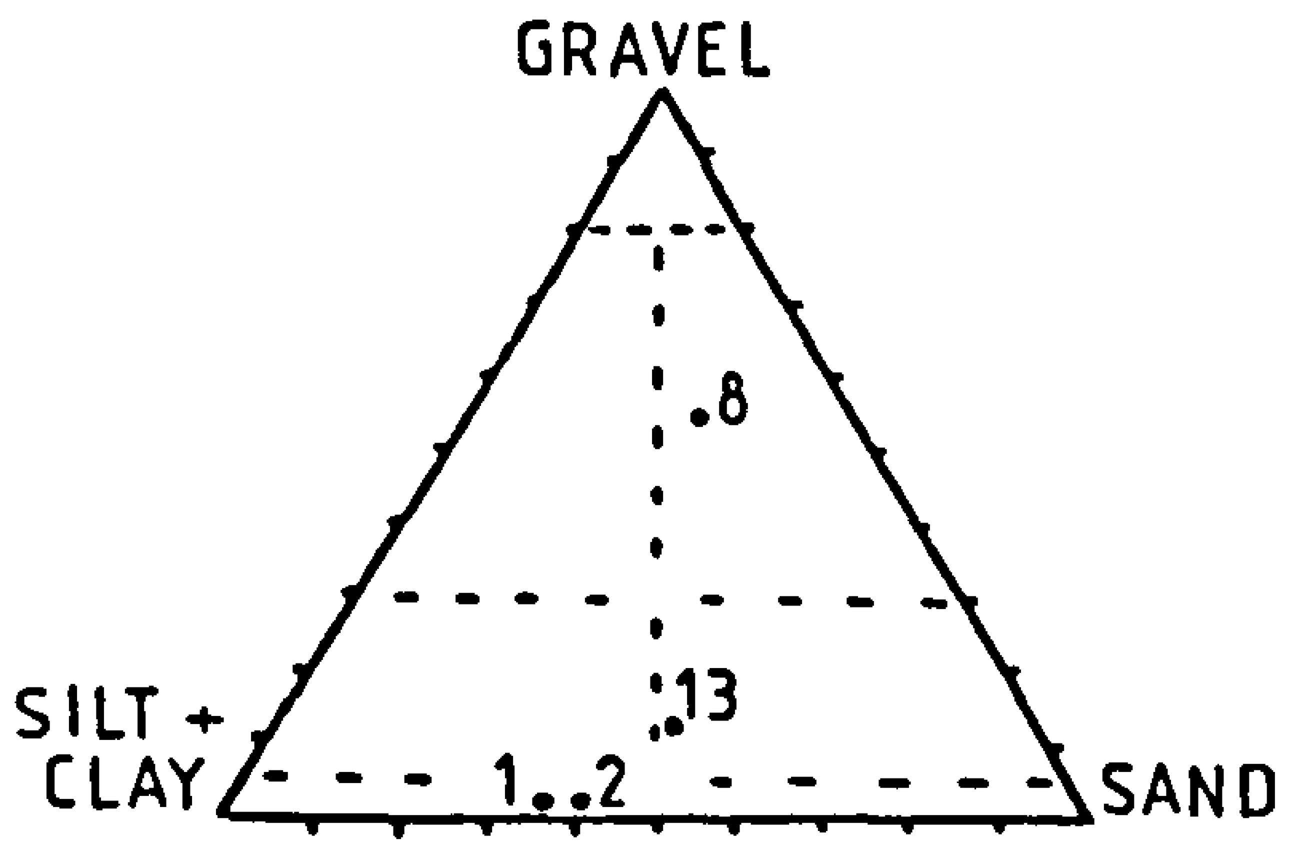


Figure 4.16 :

Field description and particle size results, TP9, Keynsham by solifluction. This seems unlikely however, since, contrary to the situation at Newton St. Loe where similar limestone slabs were noted, the area around TP9 is almost flat. It is therefore difficult to propose an origin by movement.

c) Stidham Pit B :

This was a shallow drainage trench dug near the farm entrance in 1981 at about 17m O.D. The base at 0.75m reached only the alluvial silt and clay as seen in TP9 and in the WWA trench. It consisted of an orange brown clayey silt with some fine gravel in parts, grading into more yellow green clayey material with depth. A few decayed roots and small branches and occasional shell material were recorded.

d) River Boyd exposure, near Bitton :

A section of sands and gravels is exposed in the stream bank section of the River Boyd, north of Stidham Farm and the present day course of the River Avon (Figs. 4.10, 4.17 and 4.18, and Photo 4.19). This site has already been mentioned in connection with the deposition of the large Quartzitic Sandstone boulder at Stidham Pit C.

Some 0.5-0.75m of gravel can be seen, over Lias Clay at stream level. The deposit is predominantly a sandy gravel becoming more cobbly at the southeast end of the section. Boulders of Quartzitic Sandstone are haphazardly set in this gravel, some measuring 0.45m in length.

In the central part of the exposure, and above these gravels, is 0.5m of muddy sands and silts, with a further 0.5m of orange brown silt and clay beneath the present topsoil level. Lying just above the gravels, and within the muddy sands and silts, was the mid-thoracic vertebrae of an ox (Photo 4.20). It is not possible to be more specific than a Pleistocene age for this bone.

There is a contrast between the chaotic nature of the gravel deposits and the ordered, relatively better sorted sands and silts above. The nature

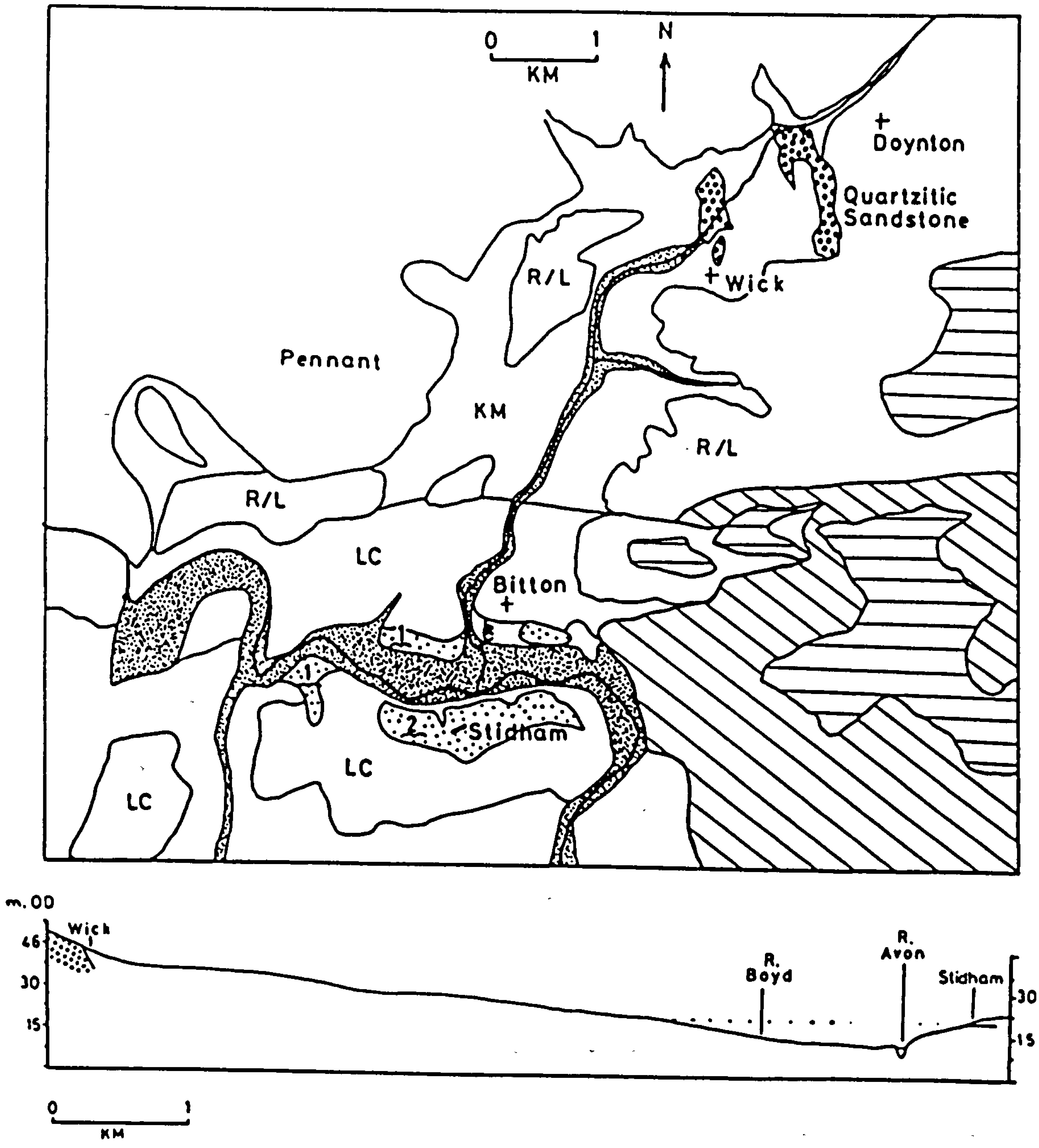


Figure 4.17 :

Geological and topographical setting of the Bitton and Stidham sites

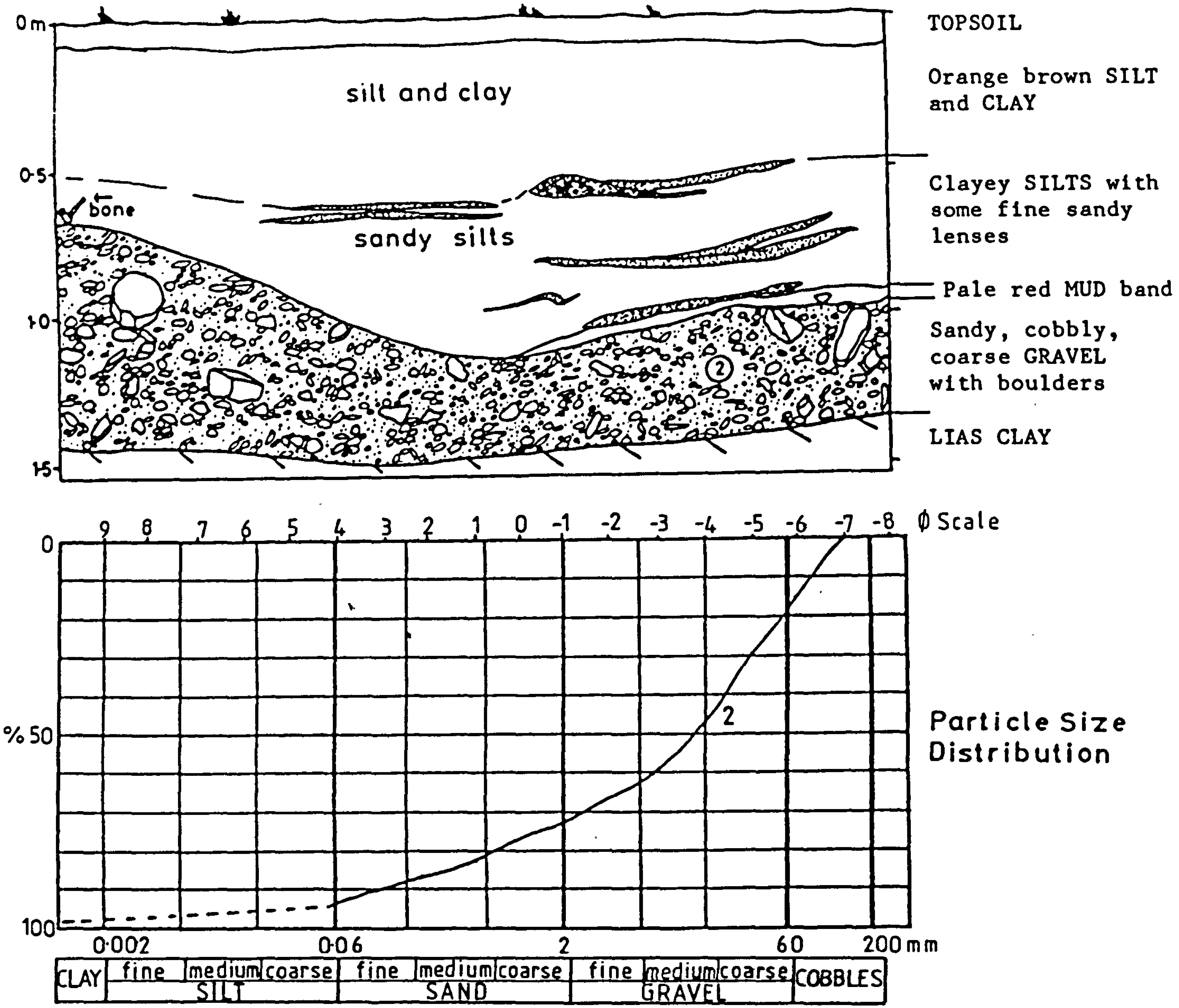


Figure 4.18 : Field description and particle size results, Stream exposure, River Boyd, Bitton

of the deposit suggests a rapid turbulent flow capable of carrying material up to boulder size, which had been made available for stream transport by the severe climatic conditions. The properties of the Quartzitic Sandstone are such that it is likely to remain as large blocks simply because of the strong, resistant nature of the grains and the siliceous cement.

The source of these boulders is at Wick, 4 miles up the River Boyd, where the stream cuts through an outcrop of Quartzitic Sandstone of Lower Carboniferous age.

The cross section at the base of Fig. 4.17 shows the differences of elevation of the parent outcrop around 46m O.D., the height of the gravel at Stidham which included Quartzitic Sandstone boulders at around 20m O.D., and the site of the River Boyd exposure at 15m O.D.

The fact that the boulders are recorded at Stidham shows that in the past the material was being carried at least this far south and being deposited around 10m above the height of the present day channel.

e) TPs A-E, Holm Mead Lane, Bitton :

In the spring of 1985 five trial pits were dug as part of an undergraduate project on the gravel resources east of Holm Mead Lane, Bitton (McConnell, 1985, University of Bristol). The field studied formerly contained a gravel pit, now partly infilled, which was mentioned by Fry (1956). In 1964, a further pit was dug out, just west of the River Boyd, as shown in Photo 4.21 (Hawkins, pers. comm.). The positions of the trial pits are marked on Fig. 4.10 and Photo 4.22 shows the upper part of the gravel terrace material exposed in TP B.

A similar succession was recorded in Pits A, B, C and E, while Pit D penetrated the alluvial muds to the south of the gravel deposit. The succession was as follows :

7) Medium brown topsoil, 0.15m thick
6) Light brown subsoil, 0.35-1.0m
5) Slightly silty, sandy, fine to medium gravel, 0.2-0.35m
4) Grey green to light brown medium to coarse sand lens, 0.03-0.18m
3) Fine to coarse, subangular to subrounded, gravel in a medium to coarse sandy matrix, generally horizontally bedded, with some thin, impersistent fine to coarse sand lenses, 0.5m
2) Very coarse gravel and cobbles, with occasional boulders of Quartzitic sandstone towards the base, unstratified and in a silty or fine to medium sandy matrix, 1.0-2.75m
1) Dark blue-grey Lias Clay, continuing.

The gravel terrace material averaged 2.3m thick over much of the survey area, increasing to over 4m around TP A. Four auger holes were sunk to assess further the extent of the terrace material.

Auger hole (a), on the western edge of the study area, showed an interfingering of alluvial muddy sands and fine gravels, and probably indicates a marginal terrace area. Auger hole (b), 100m south of TP B, showed the terrace material to be more than 3m thick at this point, while auger hole (c), 90m east of TP B, found the Lias Clay at 2.75m depth, with terrace gravel above. Auger hole (d), 100m north of TP A found only alluvium and hence must lie beyond the northern margin of the gravel terrace.

The succession found at Holm Mead Lane is directly comparable to that at Stidham Pits A and C, with lower, unstratified, coarse gravel and cobbles (= Stidham Layers 5-8), overlain by sandy medium gravel which is often horizontally bedded (= Stidham Layer 4). A sand lens again terminates this deposit (= Stidham Layer 3), while the overlying upper gravel (= Stidham Layer 2) becomes increasingly incorporated with the subsoil.

5. BRISLINGTON

This site lies on the edge of the Hanham Gorge, which here is cut through the Pennant Sandstone (Fig. 4.19). Several shale bands run through the Pennant and have a northwest trend similar to that which the River Avon follows through the solid geology from the entrance of the gorge around Hanham Mills to the northern end at Conham.

Above the gorge is a plateau like surface which is probably the result of Triassic planation; indeed a deposit of Keuper Sandstone overlies this unconformity.

On the bedrock surface are a number of gravel spreads referred to on the BGS Maps as Head. Field examination shows the main gravel deposits to be of Greensand chert, sandstones and haematite, and confirms that on the 1:10560 maps. From the mapped distribution of the shale horizons and these Head deposits it is concluded that the Head is not necessarily related to any topographic hollows over the solid outcrops.

In the 1930s, 6 Lower Palaeolithic tools made of Greensand chert were found at the surface in the grounds of Brislington House (ST 635705) (Fry, 1956). Therefore, it was decided to investigate the nature and depth of the Head and establish, if possible, the relation of the artefacts to the deposits.

TP2, BRISLINGTON :

In 1982, a pit was excavated close to the western edge of the gorge and close to the reported findspot of the tools. As the deposits were likely to be thin the pit was dug by hand. The section log and results are reproduced in Fig. 4.19.

Bedrock was encountered at 0.8m in TP2. Here the solid geology was a dark red sandstone, with the main drift material resting horizontally over it. The superficial deposit consisted of orange red, clayey silty sand with much gravel. The gravel, forming about one quarter of the material, was predominantly coarse, but with some fine to medium size pebbles. It had no preferred orientation or bedding (Sample 2/4).

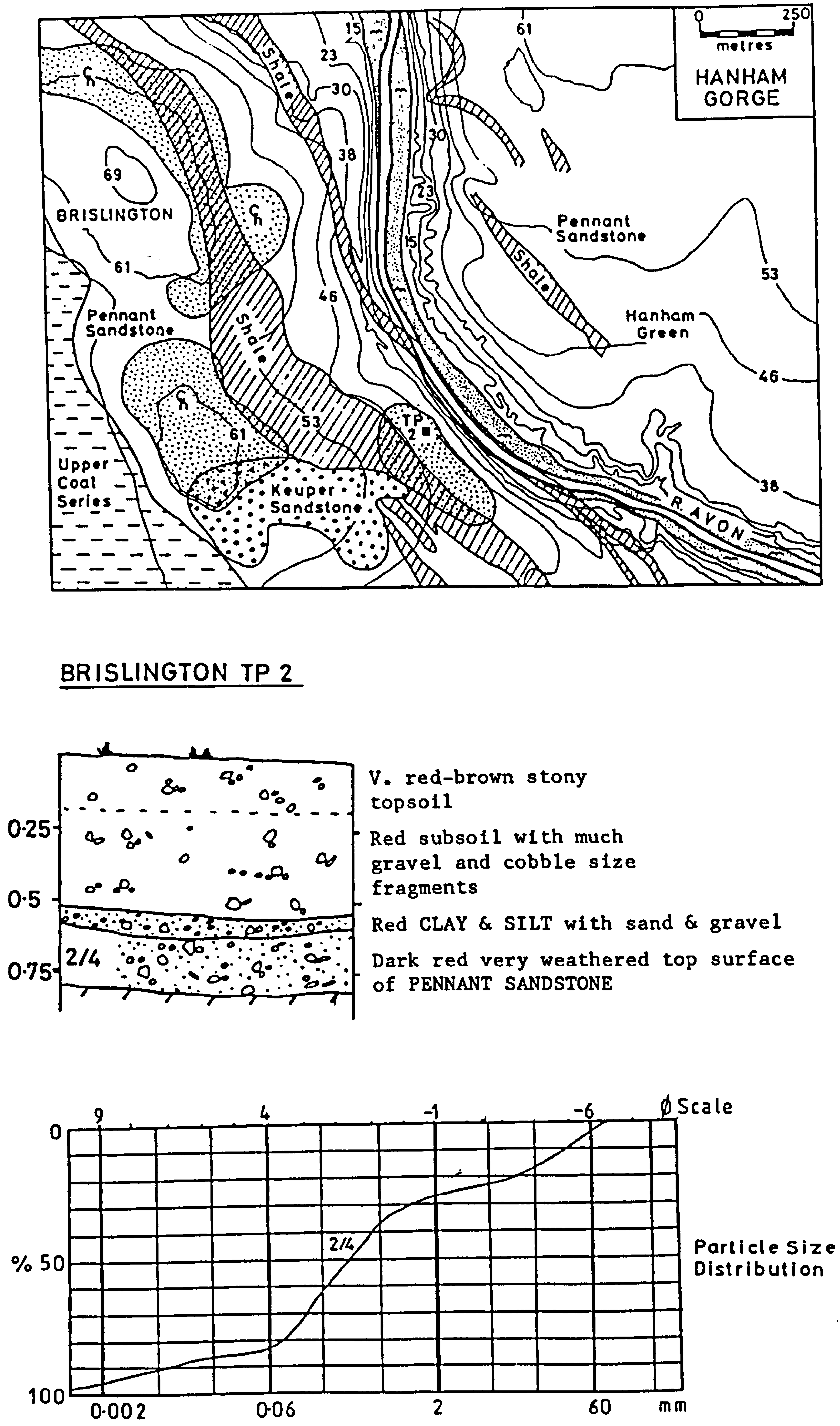


Figure 4.19 : Geological setting, field description and particle size results, TP2, Brislington

Above this band was up to 100mm of similar material, though more red in colour and containing finer gravel. Both layers contained a mixture of subangular to rounded Greensand chert, flint, local Pennant Sandstone, haematite and occasional Jurassic limestone gravel (Photo 4.23).

In the upper 0.5m the modern subsoil covered the gravelly horizons. This was a red brown loose, clayey silty deposit with many pebbles, mainly of Greensand chert. It contained charcoal and chalky flecks and its relatively modern origins were confirmed by the recovery of fragments of Medieval clay pipes from between 0.3-0.4m. The topsoil was a lighter brown, harder, compact material yet still containing many pebbles.

Thus the deposit of interest consisted of only 0.3m of material between the subsoil and the bedrock.

6. THE CITY OF BRISTOL

a) LEWINS MEAD

In the autumn of 1980, site investigations were undertaken prior to the building of an office complex on the site of St. Bartholomew's Priory in the centre of Bristol. This work included five boreholes at a surface elevation of 9.1m O.D., which penetrated the river valley deposits. Figure 4.20 was drawn from information from the drilling records.

The succession differed to some extent between the boreholes, with the rock head found from 5.5m to 15m depth. The bedrock also varied between dark red Keuper Marl, blue grey Mudstone and Quartzitic Sandstone. Only Borehole 2 recorded any true gravel deposits. Between 12.8-15m depth this reached medium to coarse red brown sand, with rounded gravel and cobbles, over fine to coarse rounded gravel with some coarse angular gravel and cobbles.

Over this (and above the bedrock in the other four boreholes) was between 3.0-8.9m of alluvial silts and clays. These were generally grey or blue grey silty clay with some organic material which was peaty in places. In BHs 1 and 5, the lower portion of the clay, just above the bedrock, included lithorelics of mudstone, while in BH 3, it contained angular gravel and cobble size sandstone fragments. These are related to hill slope disturbance and form pockets overlying the bedrock.

Above the alluvial clay was modern rubble fill and made ground.

The boreholes revealed a simple accumulation of alluvium, and hill slope deposits over the in situ bedrock. In Borehole 2 there is evidence for a small channel (giving the greatest depth to bedrock). This was infilled, firstly with mixed gravel and cobbles, characteristic of high velocity flows, and secondly with coarse sand and gravel, suggesting a decrease in current strength. This was then covered by the same blanket of finer alluvium which exists in most of the River Avon buried valley.

Figure 4.20 : Borehole logs, Lewins Mead, Bristol

b) CATTLE MARKET ROAD :

In 1981, following the collapse of the river bank and the subsequent displacement of the road surface along Cattle Market Road in the centre of Bristol, site investigations were undertaken to facilitate decisions on the repair and maintenance work required.

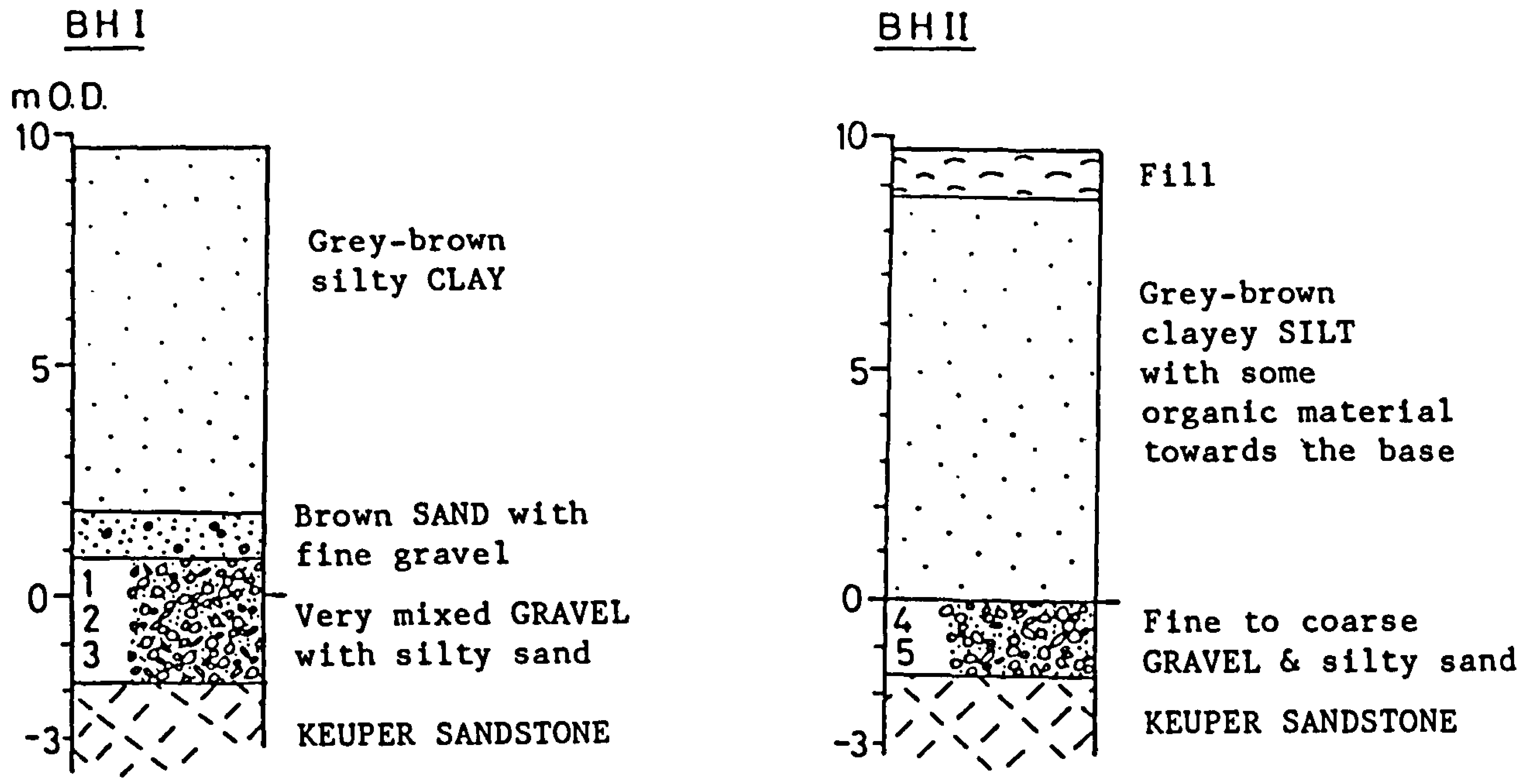
As a result, the present author was able to obtain borehole logs and samples for particle size analysis. Four boreholes were drilled and the Keuper Sandstone bedrock proved at -1.9m O.D. in each. Fig. 4.21 shows details of two of these.

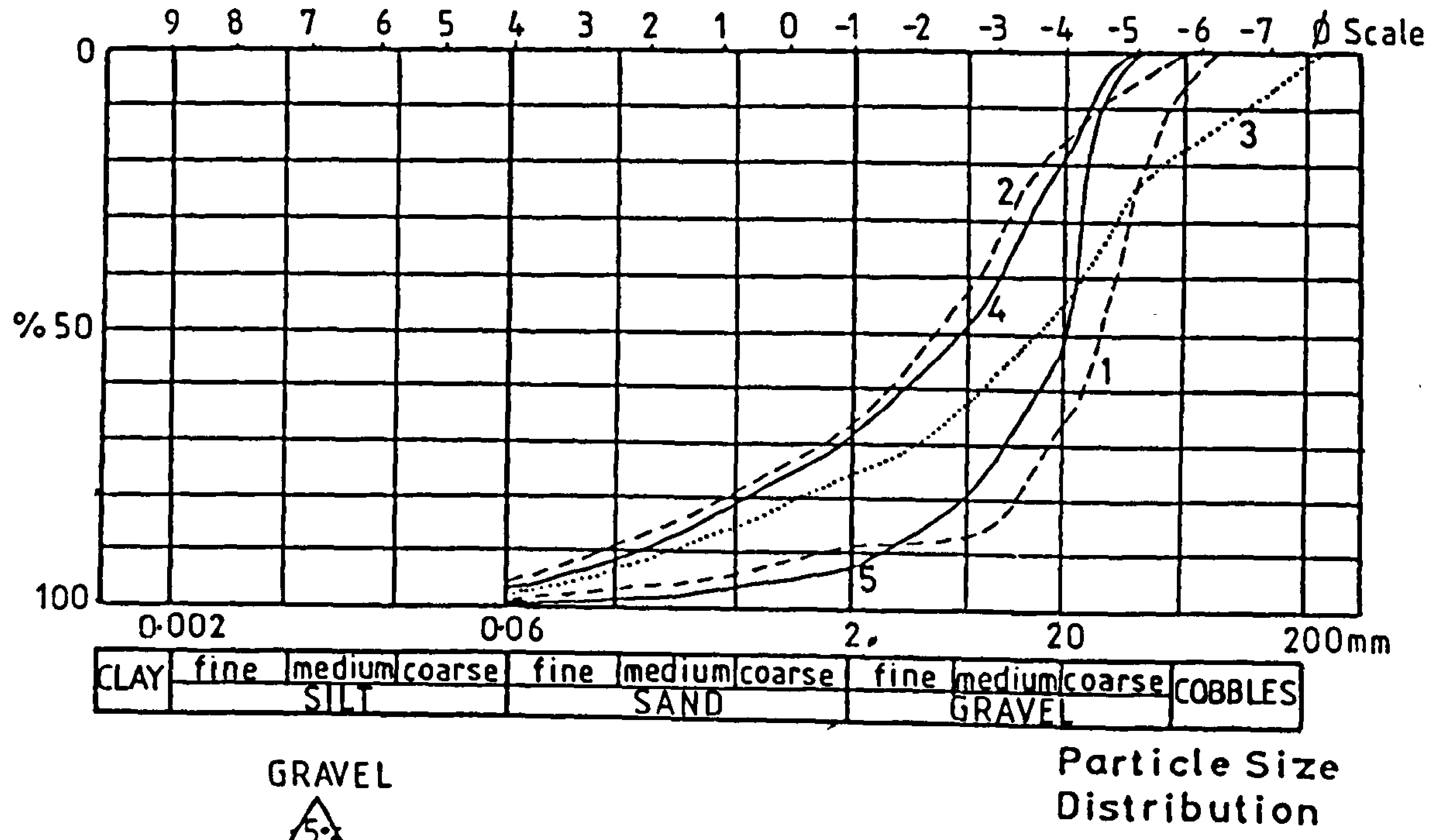
Above the bedrock was a layer of sandy gravel and cobbles varying between 0.75 and 2.6m thick. This deposit was of very dense, fine to coarse gravel in a silty sandy matrix. In Borehole 1 about 1m of fine to medium sand, with some fine gravel, lay over the main gravels.

As at the Lewins Mead site, a blanket of alluvium had accumulated over the gravels. It comprised a soft grey clayey silt with occasional organic traces and peat, and varied between 6.35 and 7.75m thick.

Thus a situation similar to that at Lewins Mead exists, with basal gravels, infilling channels in the bedrock, in turn covered by Flandrian alluvium.

Cattle Market Road





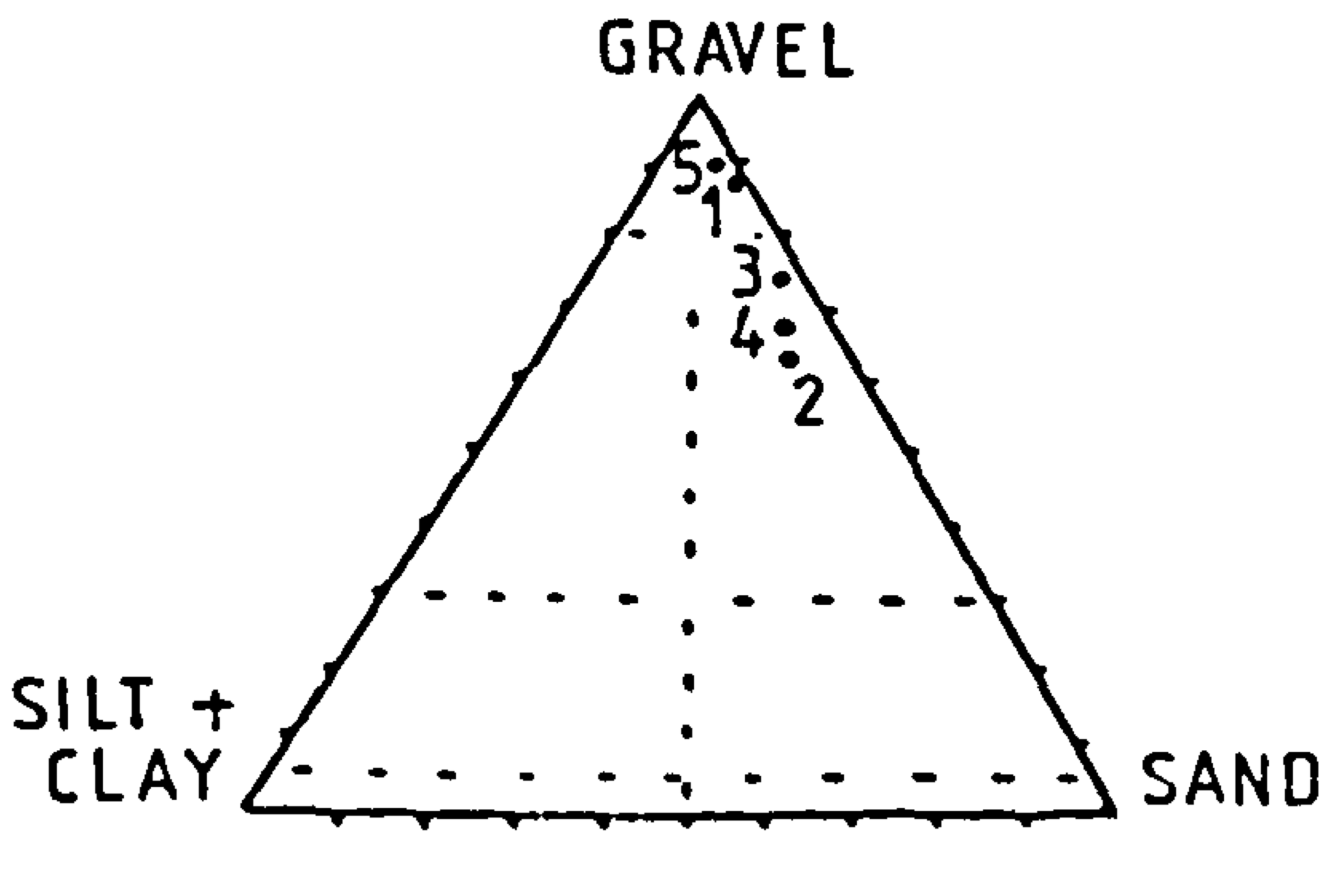


Figure 4.21 :

Borehole logs and particle size results, Cattle Market Road, Bristol

7. THE FLAX BOURTON VALLEY

To the west of Bristol, the valley of the River Land Yeo and the Ashton and Colliter's Brooks runs east-west between the Carboniferous Limestone of the Failand Ridge and Broadfield Down. It forms a broad expanse underlain mainly by the Keuper Marl, with patches of Dolomitic Conglomerate on the flanks of the limestone valley sides (Fig. 4.22). The valley is the western continuation of the lowland in which the original City of Bristol was built.

Between Long Ashton and Flax Bourton a watershed exists in the area where the valley narrows. This takes the form of a col, just above 46m O.D. from which the River Land Yeo runs to the Bristol Channel at Weston-super-Mare, and the Ashton and Colliter's Brooks east to join the River Avon at Hotwells.

It was decided to investigate the area on three counts :

1) The possibility that the River Avon, at some time in the past, flowed through the Flax Bourton Valley, and as such may have deposited materials there.

2) The possible existence of deposits which could give evidence of the blocking of this valley and/or the diversion of the River Avon.

3) The possibility that areas marked as Dolomitic Conglomerate or Head on the BGS 1" Sheets are in fact glacial till remnants (in line with the evidence found by Gilbertson and Hawkins, 1978).

Two sites were selected for trial pitting :

1) Gable Farm, Wraxall (ST 503707)
2) Gatcombe Farm, Long Ashton (ST 525695)

a) GABLE FARM, WRAXALL :

This farm lies in the Land Yeo Valley at around 30m O.D. It is flanked to the north by the Carboniferous Limestone of the Failand Ridge. In Permo-Triassic times the Dolomitic Conglomerate accumulated at the base of these rocks, with the finer grained Keuper Marl later masking these and now covering the valley bottom.

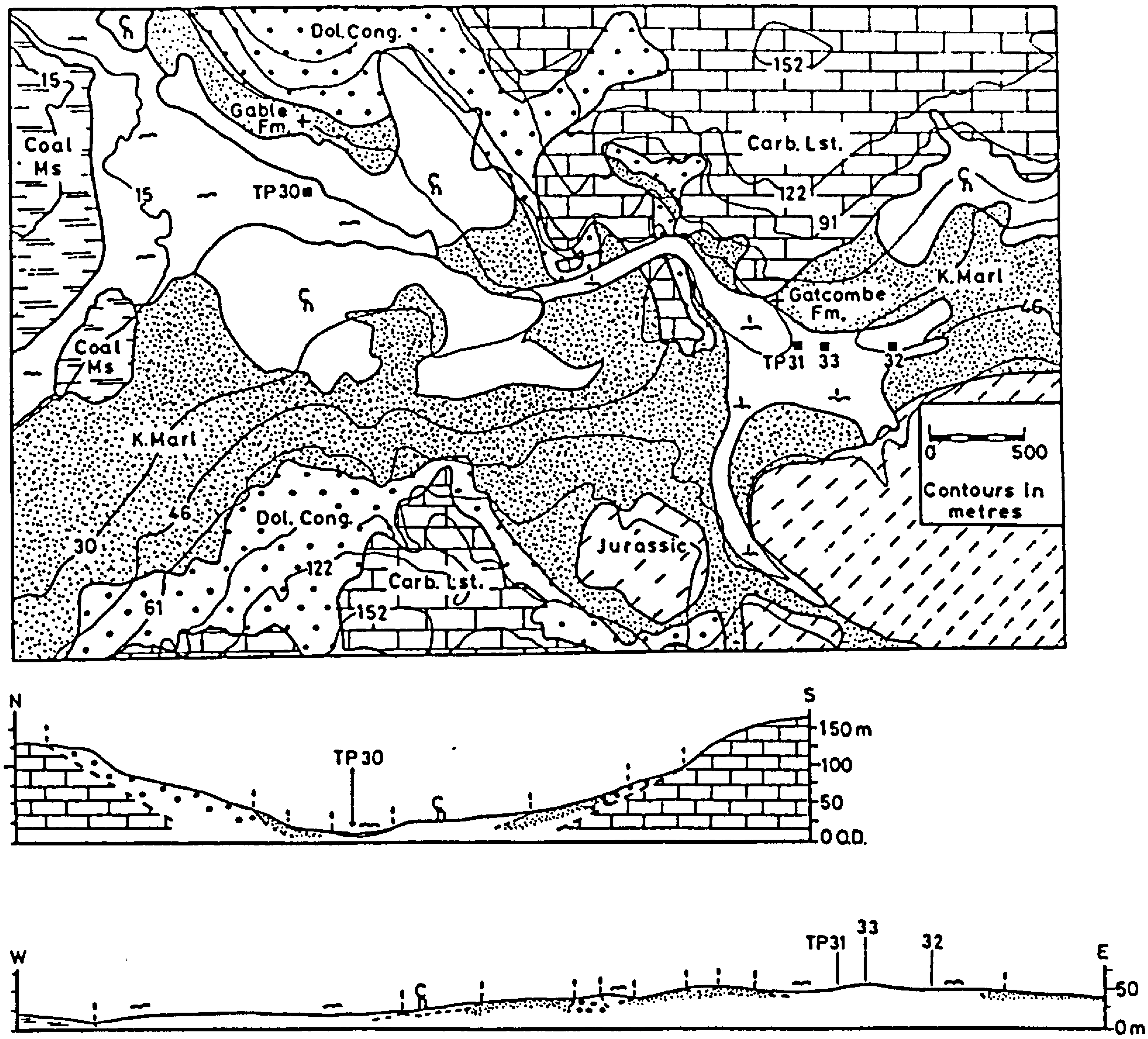


Fig. 4.22 : Geology and cross-sections of the Flax Bourton Valley, and trial pit sites

On the south side of the valley the Carboniferous Limestone rises again to form the plateau of Broadfield Down. Areas of Head deposits have built up at the base of these rocks, whilst the recent alluvium of the River Land Yeo forms a meandering deposit westwards along the valley towards the block of Coal Measures strata around Nailsea.

Between 1972-1975 a sewerage pipeline trench was dug along the valley as part of the Yeo Valley Main Drainage Scheme. In parts this reached a depth of 4-5m, around the area of Gable Farm, and a thickness of gravels and possible glacial till was reported (Hawkins, 1977).

TP30 :

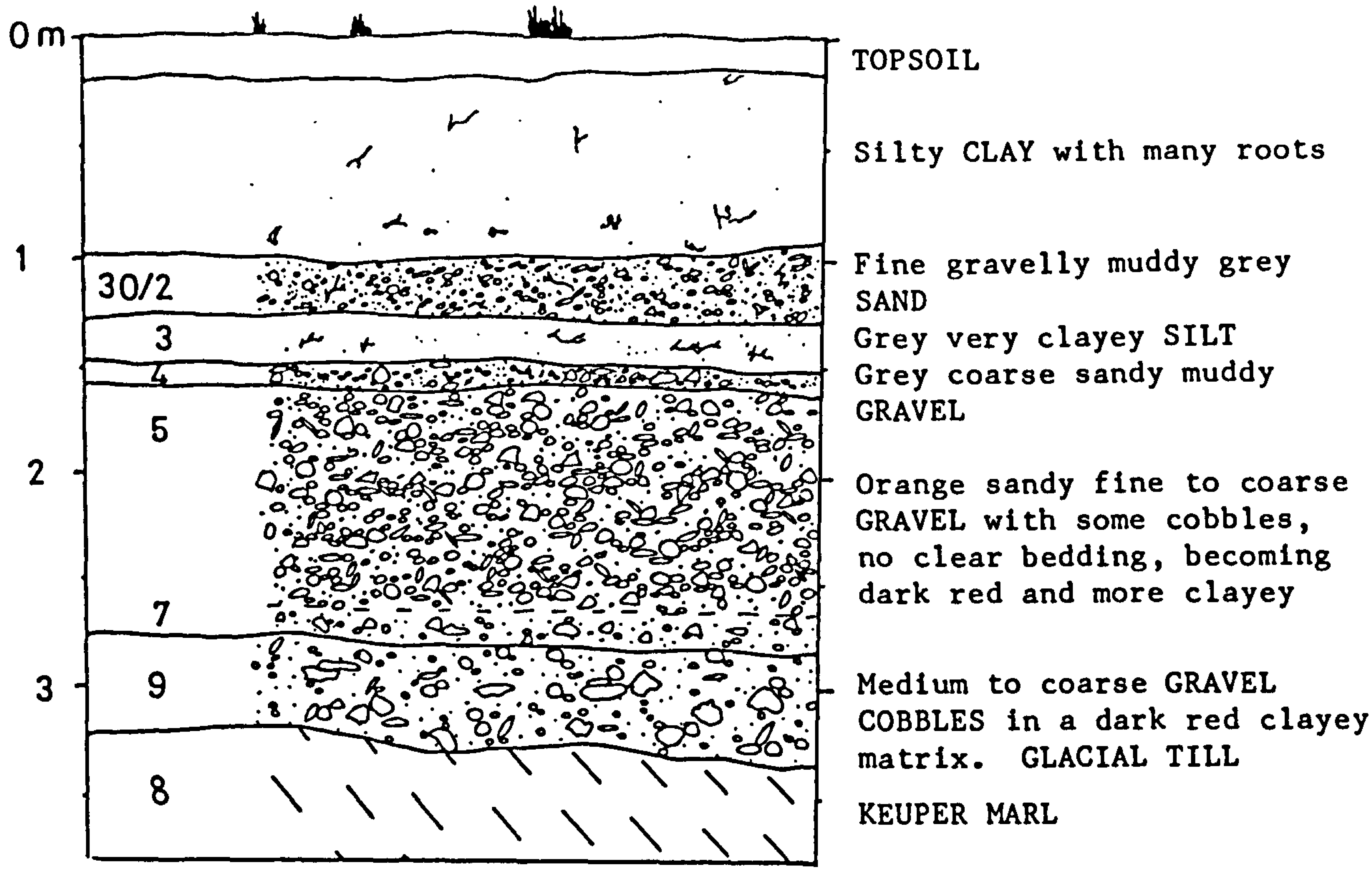
This was excavated in the field just west of Gable Wood, at a surface height of 21.3m O.D. reaching Keuper Marl at 3.2m. Below 2m, quantities of water began to seep through the gravels in the sides of the pit, so that close inspection of the deposits was not possible below this. The following succession was recorded (Fig. 4.23).

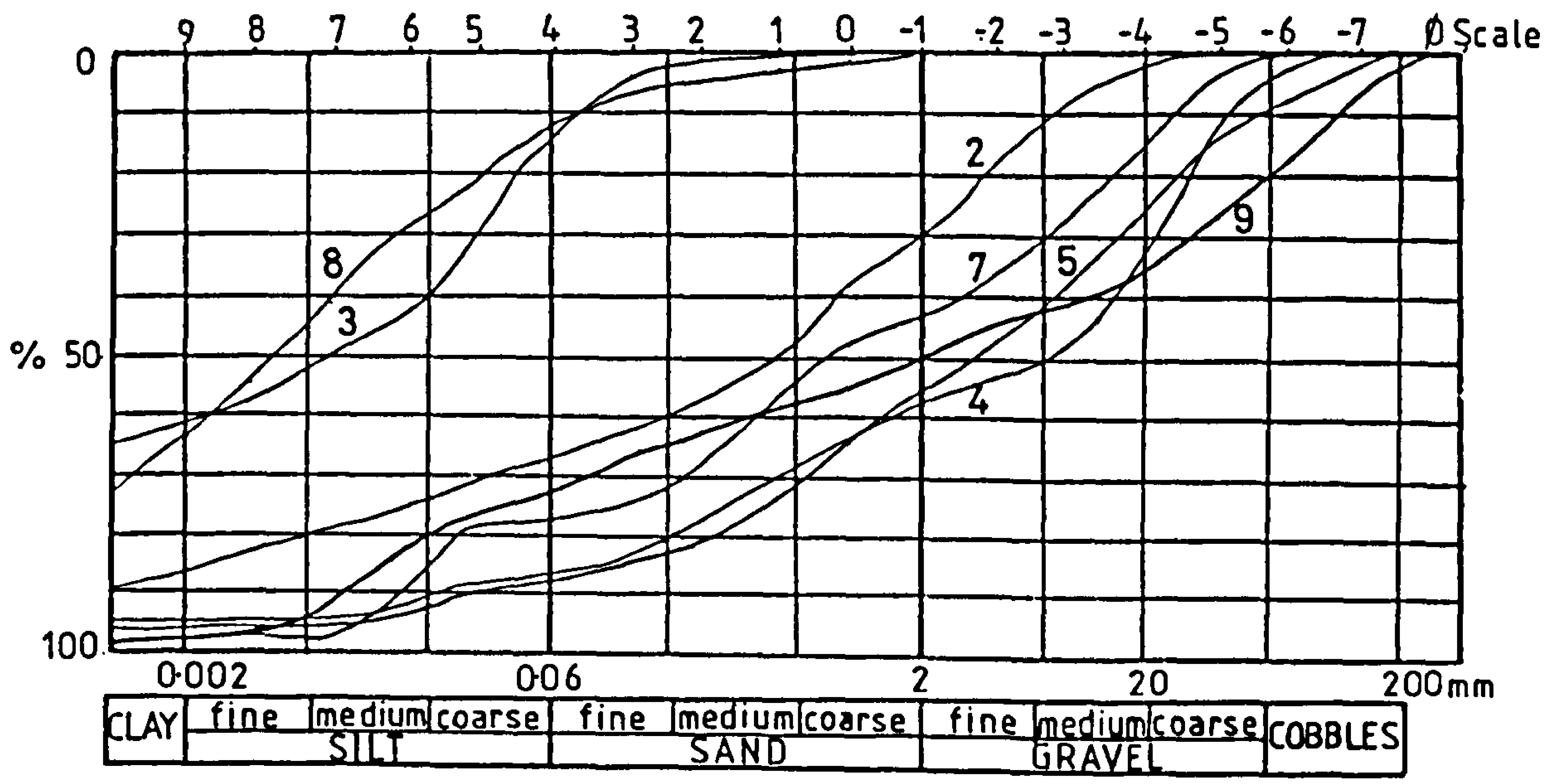
Overlying the bedrock was 0.4m of gravel and cobbles in a dark red sandy, muddy matrix. This matrix resembles the Keuper Marl but includes all grades of sand. Cobbles up to 0.25m were recorded and along with the gravel included all grades from angular through to rounded. The deposit had horizontal, undisturbed upper and lower boundaries, and was unstratified internally, the pebbles occurring chaotically in the matrix.

Above this deposit was around 1.4m of sandy, fine to coarse gravel with some cobbles. This was orange in the upper levels, becoming more dark red and more clay rich towards the base. No clear bedding could be distinguished, although near the top, small, sandier patches had been developed (Photo 4.24).

Over this gravel was 0.2m of grey, coarse, gritty sand and some fine gravel, the colour being similar to that of the upper layer. This was a grey and very clayey silt cover, only 0.25m thick. A few roots were preserved within this silt, the remains of plants that grew on the floodplain between periods of inundation.

Wraxall TP30





Particle Size Distribution

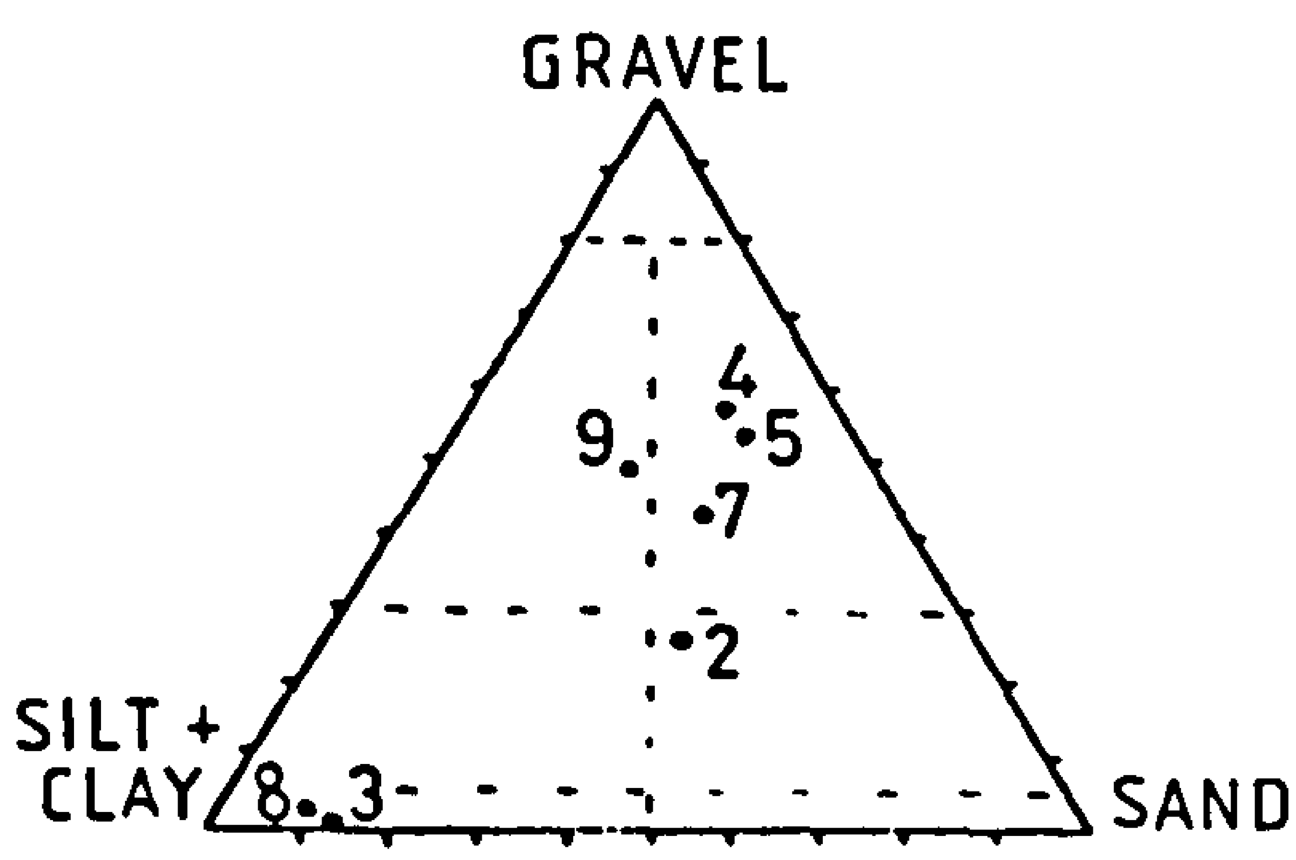


Figure 4.23 :

Field descriptions and particle size results, TP30, Wraxall

Between 1-1.25m, the grey clayey silt forms the matrix of a layer of fine gravelly sand.

Following this, the next deposit was a very dark brown peaty and fibrous silty clay, becoming less organic rich towards the modern day topsoil.

To summarise this pit, the succession is as follows :

5) Modern topsoil, 0.2m
4) Grey clayey silt, with an intercalated layer of gravelly sand, 1.2m (Samples 30/2, 3)
3) Orange, very sandy, fine to coarse fluvial gravel, 1.4m (Samples 30/4, 5, 7)
2) Fine to coarse gravel and cobbles in a dark red silt and clay matrix, 0.4m (Sample 30/9)
1) Keuper Marl bedrock (Sample 30/8).

Layer 2 was interpreted as glacial till because of the following :

a) the extremely poor sorting of the material on grain size (20% cobbles, 28% silt and clay).
b) the range of pebble lithologies present - including local Carboniferous Limestone, Sandstones and further travelled flints and cherts.
c) the range of roundness values, from fresh angular fragments to well rounded pebbles.
d) the haphazard deposition of the gravel and cobbles within the muddy matrix.

The sandier and better sorted nature of Layer 3, with a narrower range of grain sizes than Layer 2, is suggestive of a fluvial gravel. (The sedimentological differences between these deposits are more fully discussed in Chap. 5).

The material thus represents an initial glacial episode, which left a thin layer of till overlying the bedrock. Following an amelioration in climate, and the decay of the ice, the excess meltwaters flowed over the area, transporting the weathered and eroded debris produced during the cold episode. At first these materials were rapidly deposited by erratic flows, giving a mixed muddy gravel. The flows then became more constant and may have increased in strength, depositing coarser, better sorted gravels and removing most of the fines.

A third episode, not necessarily a direct continuation from the second, was the accretion of the floodplain by alluvial clays and silt. The main deposition channel of this valley had moved away from the area sampled by the trial pit and now material accumulated here only in periods of flood. This took the form of mud drapes over plant material that had become established during the drier periods.

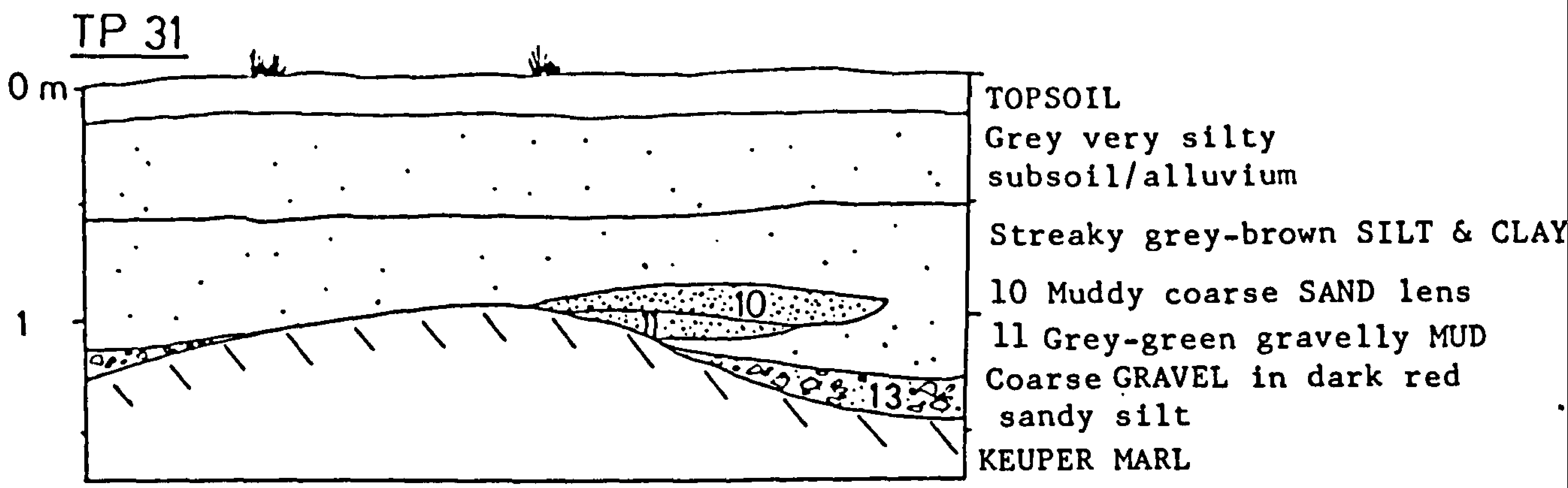
b) GATCOMBE FARM, LONG ASHTON :

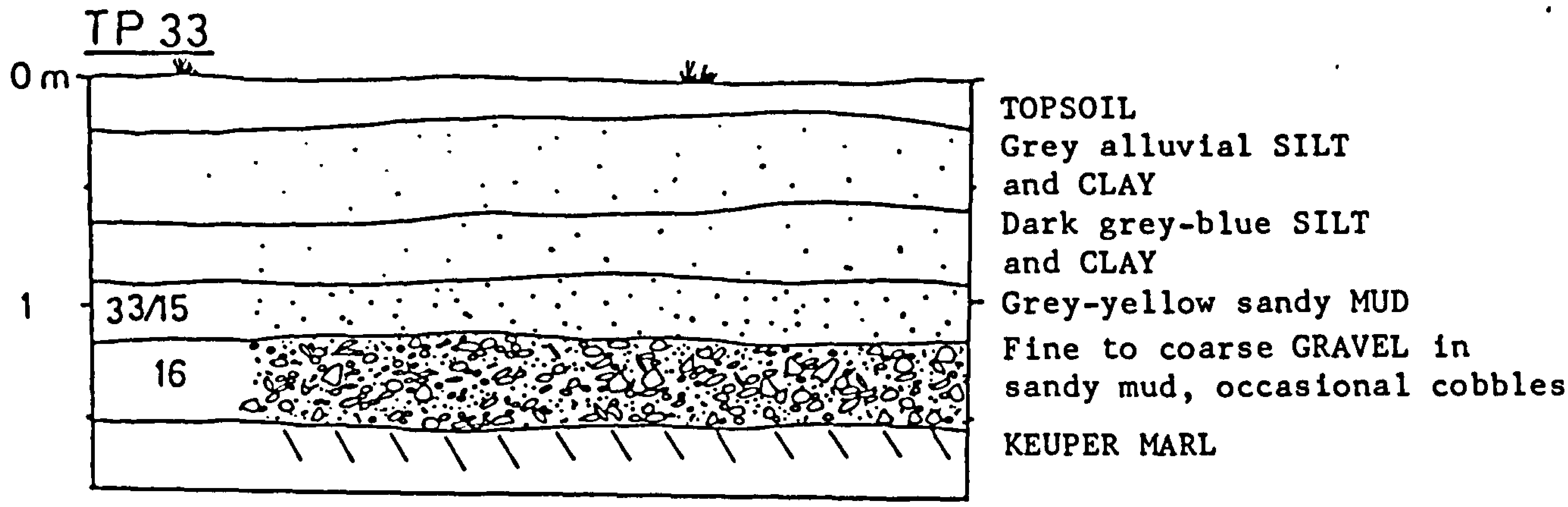
This farm lies at around the level of the present day watershed, in the area marked as the Higher alluvium on the BGS geological map. In the 1880s gravels were reported during the excavation of the GWR line, while there is today local knowledge of sands and gravels to the south of the railway cutting and some gravel material was noted in the reports of excavations at the Roman farm site north of the railway (Branigan and Cunliffe, 1966-1974). TPs 31, 32 and 33 were dug to establish the character of these deposits, and were placed in an E/W line at heights of 47m, 46.7m, and 45.8m respectively.

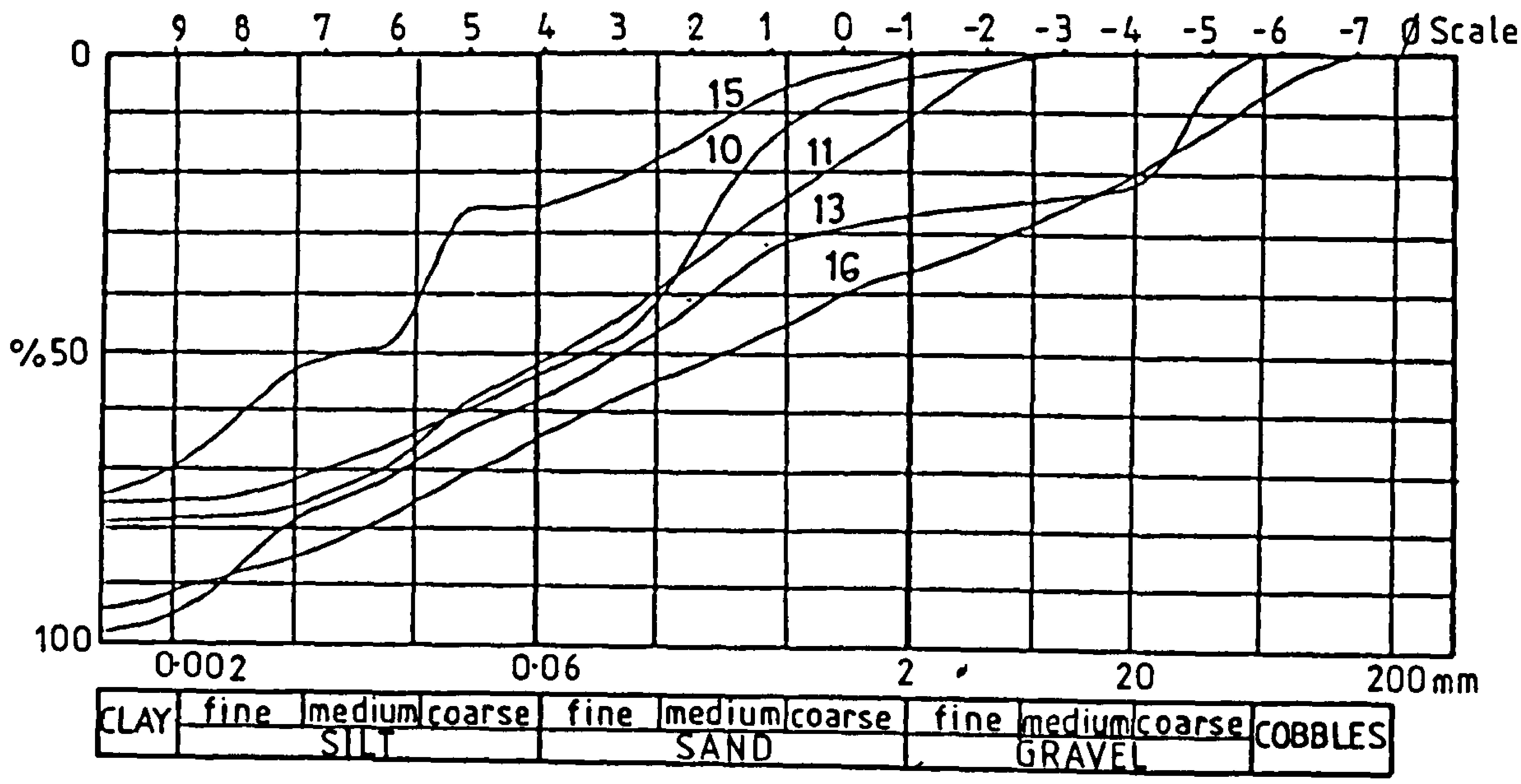
TP31 : (Fig. 4.24)

This reached Keuper Marl bedrock between 1m (north end) and 1.5m (south end). Thin layers of sands and gravels occupied the hollows in the uneven bedrock surface (Photo 4.25). The lowest layer (Sample 31/13) was a thin gravelly mud, 0.2m at most, with both rounded and angular pebbles in its red clayey silty matrix. The clasts were generally coarse to medium in size and were very weathered, some even partially rotted. They were mainly of local Carboniferous Limestone, with one or two fragments of oolitic limestone.

Gatcombe Farm







Particle Size Distribution

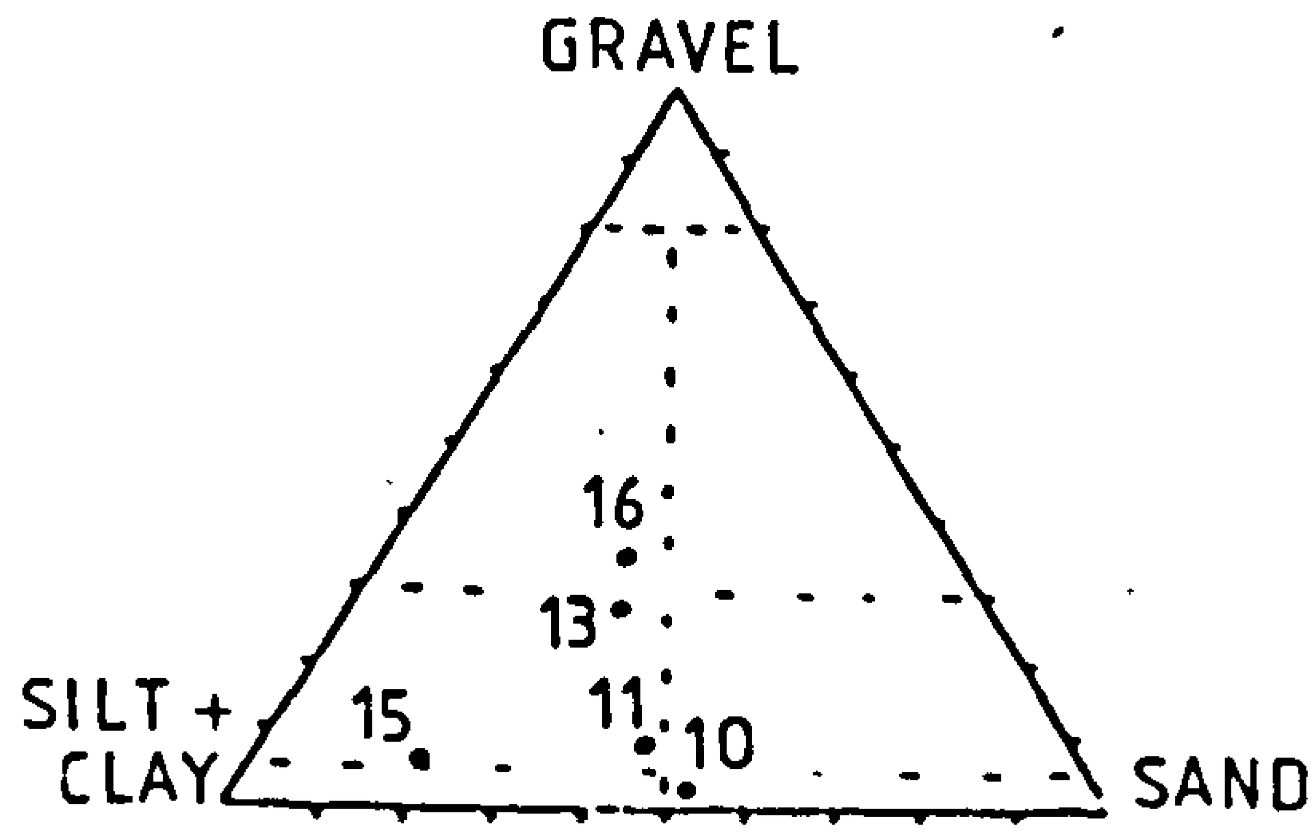


Figure 4.24 :

Field descriptions and particle size analysis, Gatcombe Farm

A grey brown clayey silt, 0.7m thick at most, covered both the Keuper Marl and this gravelly deposit. Set within this alluvium, and partially over the highest point of the bedrock, were two thin sand lenses. The uppermost, 0.1m thick and 0.3m in length, was a medium brown, predominantly medium sized sand (Sample 31/10). It was extremely poorly sorted, containing 10% gravel and 25% clay; no bedding was noted within the lens. Below this was a smaller lens of grey green, very poorly sorted, gravelly sandy mud (Sample 31/11).

Above all these deposits was 0.3m of grey very silty subsoil or alluvium with a high humic content.

The position and nature of the sand lenses within the alluvium suggests that the materials have been disturbed by cryoturbation. This process would have forced the sand lenses into the clayey silt above, and possibly accounts for the uneven Keuper Marl surface.

TP32 :

This, the easternmost trial pit, found the following succession :

3) Medium brown topsoil, 0.4m
2) Grey brown clayey alluvial silt with some iron staining and organic patches and roots, becoming more grey with depth, 0.55m
1) Dark red clay with an intercalated pale grey-green clay - Keuper Marl, from 0.95m depth.

TP33 :

This was positioned between TPs 31 and 32.

The flat top surface of the Keuper Marl lay at 1.5m. Above this was 0.4m of a gravelly deposit, very similar to that seen in TP31. It was a predominantly medium to coarse gravel with some cobble sized material (Sample 33/16). The matrix was coloured grey green in contrast to the matrices of TP31/13 and TP30/9, which were both of dark red clayey silt

and therefore very similar to the Keuper Marl. Generally the pebbles were moderately rounded but included also some angular fragments and predominantly consisted of local Jurassic limestones.
Above these gravels were a series of alluvial silts and clays. The lowest consisted of 0.2m of grey yellow sandy mud (Sample 33/15). Above was 0.3m of dark grey blue, more clayey silt, and then a further 0.3m of dark grey silty clay, with some yellow iron rich streaks. Thus a gradual fining upwards was observed within the alluvium.

Samples 31/10 and 11, 32/14, and 33/15 were all sieved and checked for both foraminifera and molluscan remains, but unfortunately none were preserved.

Interpretation of the deposits at Gatcombe Farm :

It can be seen that TPs 31 and 33 are very similar, with a maximum thickness of 0.4m of gravel between the alluvium and the bedrock. This gravel may be the eastern equivalent of the till encountered between fluvial gravels and the bedrock at Wraxall TP30.
The deposits at Gatcombe have the same characteristics :

1) very poor sorting, with 27-35% gravel and 35-42% mud.
2) a mixture of both rounded and angular fragments haphazardly deposited with no preferred orientation or bedding.
3) a matrix of dark red clayey silt (TP31) and of grey green clayey silt (TP33).

Alternatively, the gravel deposit of TP33/16, which is dominated by local Jurassic lithologies, may be the result of solifluction off Dundry Hill. The slope deposits seen at Bathampton however did not show such a range of grain sizes, nor the relatively high mud content found in the Gatcombe material. In view of this the deposit has been interpreted as of glaciogenic origin.

TP31 shows evidence of cryoturbation affecting the sand lenses above the till like material, and also possibly the Marl bedrock. Since periglacial conditions are necessary for the development of cryoturbation features, then the latest possible date for this disturbance is the Devensian period, and the grey brown clayey silt into which the sand lenses have been forced must have accumulated prior to this deformation.

Therefore in TPs 31-33 there is evidence of a period of alluvial accumulation at a height of around 46m O.D., prior to the end of the Devensian. The uppermost deposit of grey alluvium is very similar in appearance to the Flandrian silts found elsewhere in Somerset, but its height above sea level makes this dating questionable.

The trial pits have proved that the material shown on the Geological Sheet at First Terrace material or Higher estuarine alluvium to be of the latter type.

CONCLUSIONS :

In addition to the infills of the buried valleys at Tickenham, Court Hill and Swiss Valley, there is evidence of glaciogenic deposits on the top of the Failand Ridge e.g. at Moat House Farm (Colbourne et al., 1973) and at Leigh Woods and Abbots Leigh on the edge of the Avon Gorge.

The Geological Survey Ashton Park borehole (Kellaway, 1967) found 1.5m of dark red mud with pebbles and fragments of Greensand chert, at 18m O.D. This can now be identified as typical of the chert rich till deposits found in the area (Gilbertson and Hawkins, 1978). The Wraxall and Gatcombe trial pits also revealed glaciogenic deposits on the floor of the Flax Bourton valley at 18m and 46m O.D. respectively, although the two deposits are not necessarily suggested to be equivalent.

At those sites investigated, the tills are the oldest deposits found above bedrock, with any local fluvial/fluvioglacial gravels resting on top of them. It appears probable that the glaciation has removed any previously deposited materials which might have included sediments related to a former course of the River Avon.

Hence the evidence suggests that the River Avon has not flowed through the Flax Bourton valley at least since the glacial episode represented by these till deposits.

The higher alluvium described from Gatcombe is suggested to be of Ipswichian date, later affected by Devensian cryoturbation. Thus the glacial material would date to the Wolstonian or Anglian period.

8. CHAPEL PILL

North from the Cumberland Basin, the River Avon flows along a northwesterly line coincident with major jointing in the Carboniferous Limestone. Beyond Sea Mills the river loops around to the southwest, in the section known as the Horseshoe Bend, and flows past the Carboniferous Limestone and Pennant Sandstone mass at Shirehampton. It then regains its northwesterly line through the alluvial flats and continues straight to enter the Severn at Avonmouth.

Chapel Pill Farm lies on the slopes within the Horseshoe Bend. With uniclinal shifting of the river channel, evidence of fluvial erosion and deposition would be expected to be preserved on the inside of the loop. From the northern side of the river, looking towards Chapel Pill Farm, upper and lower terrace features can be seen around 15m and 30m O.D. respectively. The materials resting on the upper terrace are of a coarse gravel type and recorded on the Geological 1:10560 sheet as No. 2 terrace gravels which here overlie Keuper Marl and Dolomitic Conglomerate bedrock.

The fields around Chapel Pill Farm have yielded many finds of Lower Palaeolithic tools over the years. This has already been mentioned in Chapter 2 and will be discussed more fully in Chapter 6.

Between 1980 and 1984 several exposures were recorded around Ham Green and Chapel Pill (Fig. 4.25) which showed the nature of the deposits and gave some evidence of the complexity of the depositional history of the Quaternary in this area.

a) EAST OF HAM GREEN :

In 1980 a sewerage pipe trench was dug to the northeast of Ham Green Hospital. This reached depths of between 1-2m and revealed the following :

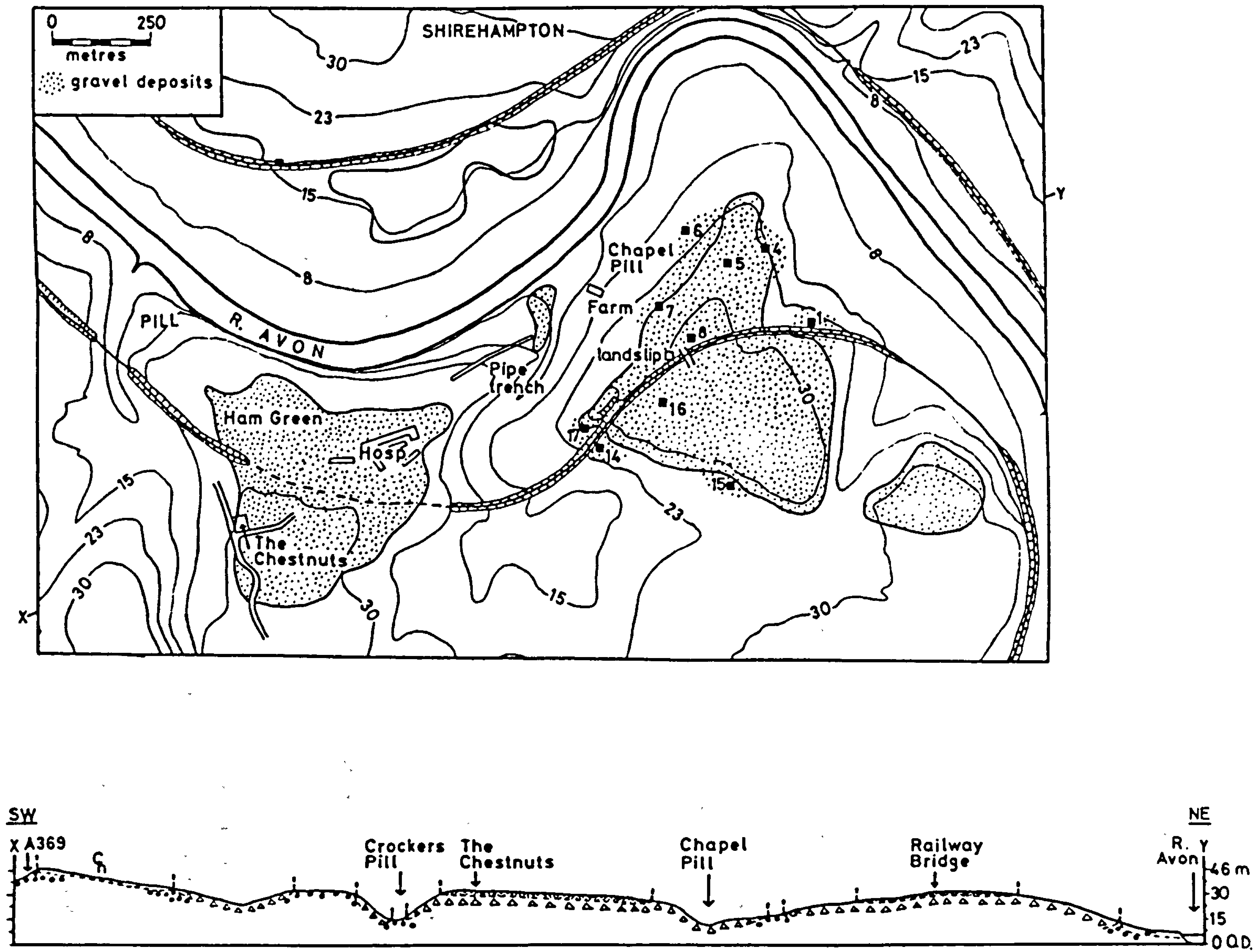


Figure 4.25 :

Gravel deposits at Chapel Pill and Ham Green

a) NE end
3) dark to red brown topsoil, 0.2-0.3m
2) grey brown, becoming more red brown, slightly gravelly sandy silt and clay (hillwash), 0.8-1.0m
1) very weathered Dolomitic Conglomerate, 0.4m, continuing.

b) SE end
3) dark to red brown topsoil, 0.2m
2) red brown subsoil, 0.3m
1) grey green mudstone band with a dark red silty lens (Keuper Marl), 0.5m, continuing.

This stratigraphy was confirmed by sections drawn during the City of Bristol Museum archaeological excavation of a Medieval Pottery kiln site just to the south of this pipe trench, in 1976. These excavations found similar topsoil and subsoil over the red and green silty clays of the Keuper Marl.

b) CHAPEL PILL FARM :

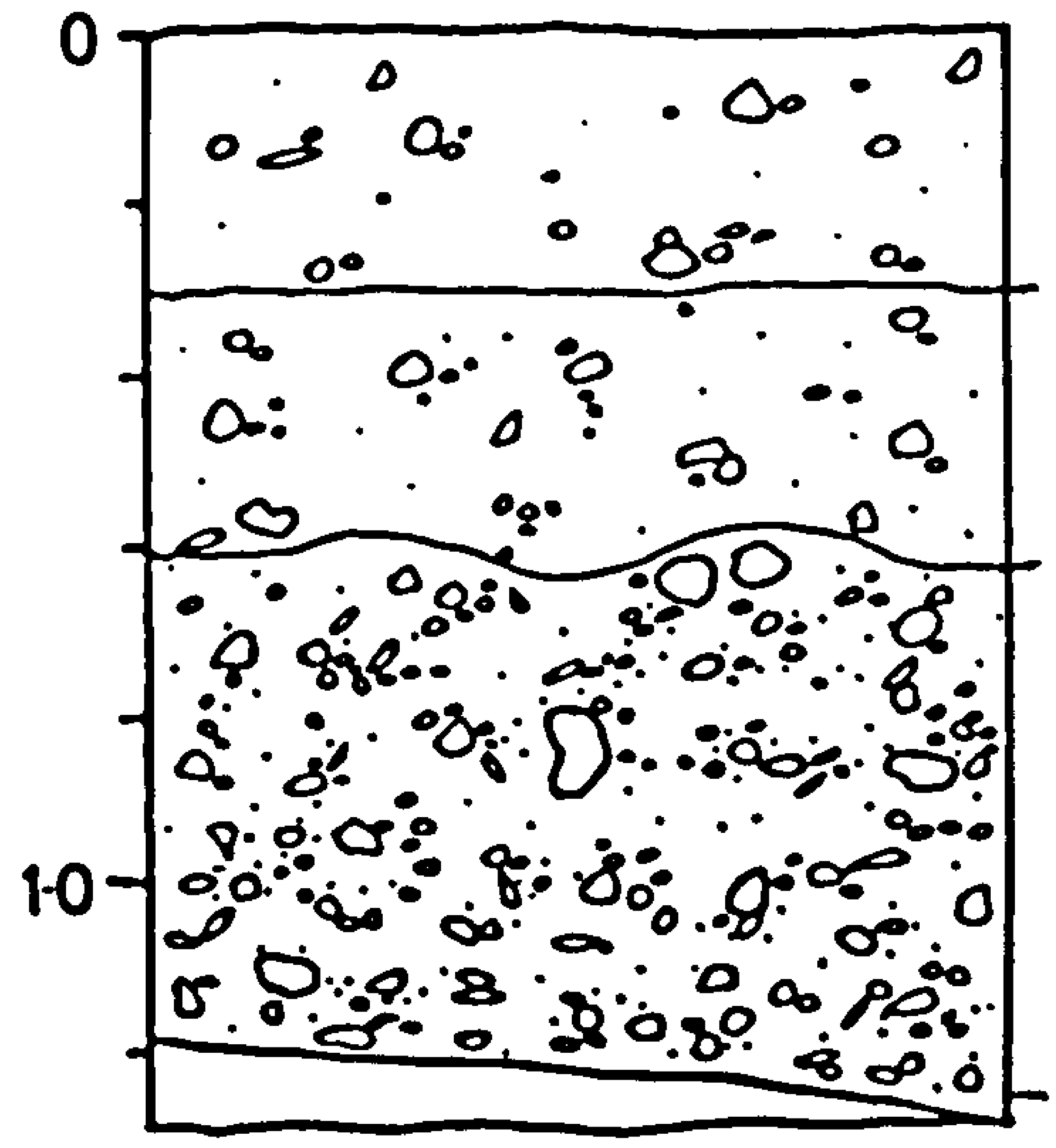
Trial Pits : During September 1981, a series of trial pits was dug for the Bristol Minerals Company to investigate the possibility of exploiting celestine deposits. (These were formerly worked in the area from pockets in the Keuper Marl.) Several of the trial pits were of interest to the present study, and are marked on Fig. 4.25.

The best example of the gravel deposits was found in TP8, by the access road bridge which runs across the railway cutting. Here, as seen in Fig. 4.26 and Photo 4.26, the gravelly deposit achieved a thickness of 1.5m over the Keuper Marl bedrock. It consisted of a matrix of red brown silt and clay, enclosing many pieces of fine to coarse, rounded to angular, gravel and small cobbles. These had been incorporated into the lighter brown subsoil and grey brown topsoil. The contact between the gravel and the bedrock slopes very gently southwards.

Other trial pits showed a similar deposit of lesser thickness, with the maximum gravel concentration on the highest parts of the Chapel Pill rise, north of the railway line. These thicknesses are as following :

Chapel Pill:

TP8



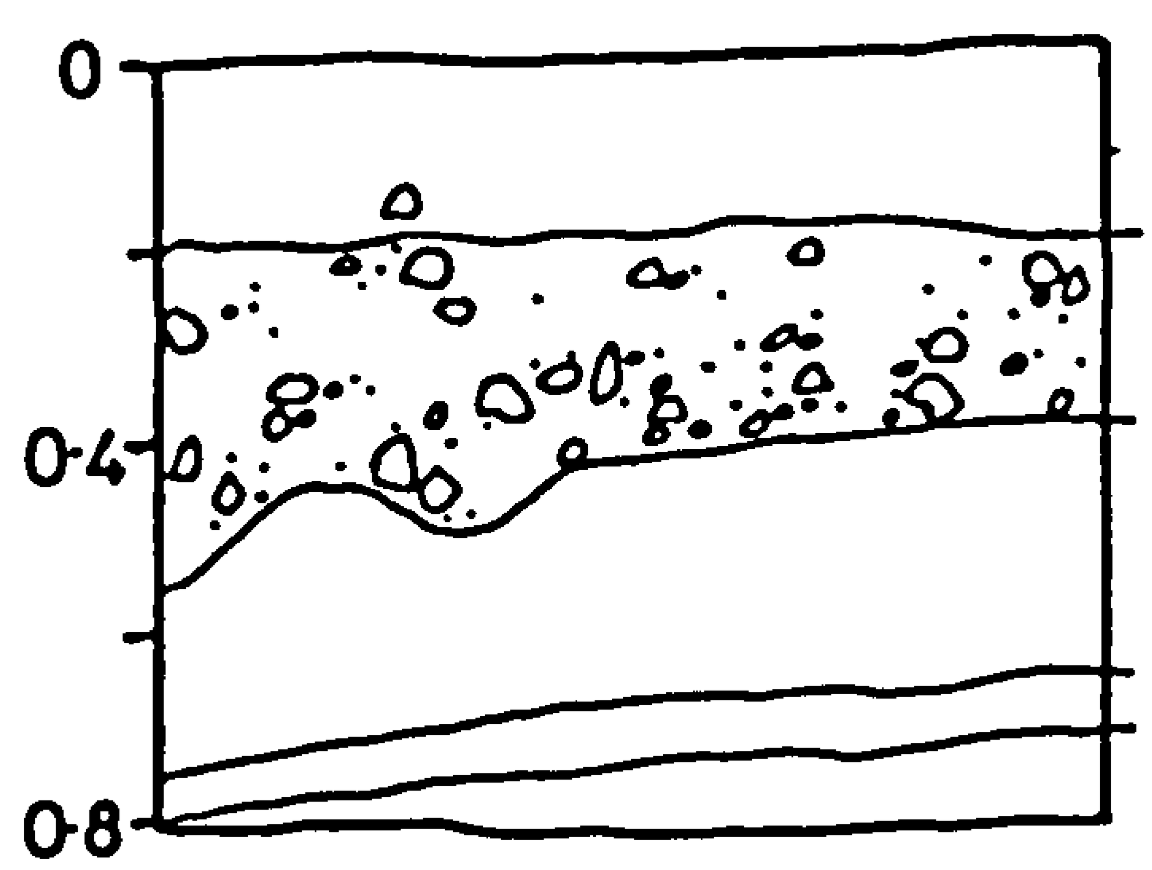
Grey brown gravelly topsoil

Yellow orange SILT and CLAY with some medium gravel

Dark red-brown CLAY and SILT with many cobbles and fine to coarse gravel

Keuper Marl, dark red silty clay

Railway Cutting East



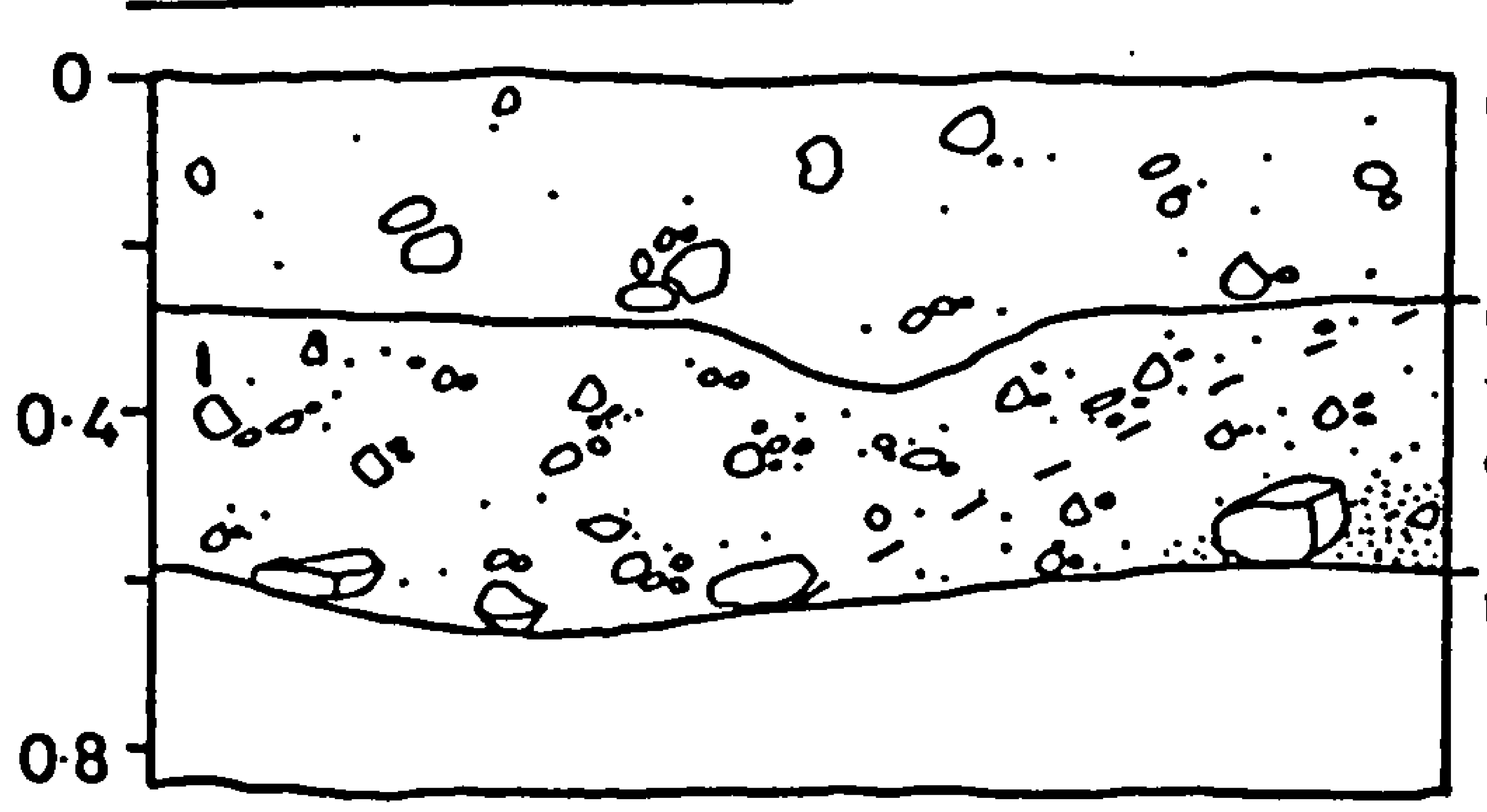
Medium brown topsoil

Orange-brown clayey soil becoming dark red-brown and gravelly at base

Light grey-green KEUPER MARL

Dark red Keuper Marl lens
Dolomitic Conglomerate

Landslip section



Grey brown topsoil with occasional to some cobbles and coarse gravel

Orange-brown SILT & CLAY with fine to coarse gravel & cobbles. Sandy area at base within an area of black mottled matrix. Larger cobbles generally at base.

Dark red Keuper Marl

Figure 4.26 : Field descriptions, Chapel Pill

TP4	0.4m	TP14	0.3m
TP5	0.55m	TP15	0.25m
TP6	0.3m	TP16	0.45m
TP7	0.5m	TP17	0.35m
TP8	1.5m		

c) CHAPEL PILL RAILWAY CUTTING :

Two further exposures of this deposit were studied in the sides of the railway cutting (Fig. 4.26). The first was a section dug by hand towards the eastern end of the cutting to try to establish the extent of the deposit in this direction (Photo 4.27). From 25.5m O.D., 0.25m of medium brown topsoil included several large pebbles (up to 100mm) of chert and sandstone. Below this was a red brown layer of coarse sandy silt and clay with many clasts of the same lithologies. This deposit was 0.35m thick at most and overlay a green mudstone band, which formed the top of the Keuper Marl.

The gravel of the main deposit was contained within the finer matrix, showing no alignment or bedding and including both well rounded, very smooth chert pebbles, in juxtaposition to fractured and angular examples. The whole deposit lacks any evidence to support a normal fluvial character. The two most likely possibilities are :

1) an original gravel rich veneer which suffered solifluction and frost disturbance in a cold environment and thus became incorporated within a finer matrix of silt and clay during downslope movement.
2) a conglomeration of mud, sand, gravel and cobbles deposited by glacial ice.

d) LANDSLIP SECTION :

The second exposure in the railway cutting resulted from landslipping following heavy rain in the spring of 1982. Around 20 metres west of the access road bridge, a slip occurred at the top of the cutting, which removed much of the vegetation and topsoil. The vertical backwall of this slip exposed the in situ geology (Fig. 4.26 and Photo 4.28).

The topsoil consisted of 200-300mm of grey brown loam, including some cobbles and coarse gravel. The average length of these pebbles was between 50-100mm and they were predominantly of Greensand chert and sandstone (Pennant?) with occasional Carboniferous Limestones and quartzite.

Below this layer was the main deposit, which was made up of two units : On the western side of the exposure was about 200mm of orange brown silt and clay with many cobbles and much coarse gravel. In the exposed section of 1.5m width, 6 cobbles of over 150mm length were noted, generally, though not exclusively, towards the base of the layer, consisting of Pennant and Quartzitic sandstones. The matrix also became slightly more sandy with depth. On the eastern side the same layer was found, though here the orange brown muddy matrix was speckled with black staining. (This differentiation was also found on the Ham Green House site.)

The largest boulder of the section was found on the east side and at the base of the gravel deposit. It measured 230 x 70 x 100mm, and was made of sandstone. Another boulder, of strong siliceous sandstone, was found to the east of this landslip, in disturbed topsoil, and measured 200 x 140 x 130mm and weighed 3.915 kg.

Lying below this gravel and cobble layer in the exposed section was the slightly undulating top surface of the Keuper Marl bedrock, here a dark red mudstone.

The main gravel and cobble deposit is seen to be fairly consistent throughout the Chapel Pill area. It can be traced from the west end of the railway cutting (0.3m thick), to the east end (0.35m thick). The greatest depth is found at the access bridge (TP8, 1.5m thick), and the deposit is confined to the area above about 23m O.D. on the Chapel Pill rise.

e) "THE CHESTNUTS", HAM GREEN (Fig. 4.27) :

The final area of study was west of Ham Green Hospital where a private housing development resulted in several exposures in the spring of 1984.

The site lies at 30m O.D. at the junction of the Bristol to Pill road and the entrance to Ham Green Hospital. On the first visit to the site several drainage trenches were open, providing short, separate sections. On the next occasion, a continuous foundation trench was recorded. (Part of this section is reproduced in Fig. 4.27).

From these the overall succession was established :

Layer 4 : The loamy topsoil varied from dark to light brown and included much medium to coarse gravel and cobbles. It had suffered some disturbance in parts by the building works. 0.2-0.4m thick.

Layer 3d : In the southern part of the site, below the topsoil, lay a yellow orange clayey silt with many small rounded pebbles of quartz and chert. 0.2m thick. (Photo 4.29)

Layer 3c : Over most of the site, below the topsoil, and Layer 3d, where present, was a yellow orange sandy silt and clay, with much medium to coarse gravel and cobbles. This gravel consisted of mainly Greensand chert with many small rounded quartz pebbles, some flints and coarse red sandstones and quartzite. Also included were very weathered lithorelics of red and green Marl. 0.2-0.6m thick.

Layer 3b : In the northern part of the site, Layer 3c became a more orange and black speckled silt and clay with gravel, similar to that seen in the Chapel Pill railway cutting. This material lay beneath the true Layer 3c. Up to 0.5m thick. (Photo 4.30)

Layer 3a : A further layer of orange brown silty clay with occasional fine to medium gravel lay below Layer 3c in the most eastern part of the site, and below Layer 3b to the north. 0.2m thick. (Photo 4.31)

Figure 4.27 :

Field descriptions and particle size results, Ham Green House site

Layer 2 : One small area of blue green silty clay was found, below 3c, which was possibly the top of the Keuper Marl.

Layer 1 : This was a dark red silty clay with an uneven top surface (Keuper Marl). 0.1-0.2m thick, continuing.

The main deposit therefore is a mixed gravelly material with a clayey matrix, showing speckled colouring near the base. The pebbles range from fractured, angular Greensand chert and flint to small well rounded quartz and haematite. The predominance of durable, non-calcareous and far travelled material, together with the lack of any clast orientation and bedding suggests that this is a glacial till deposit.

It can be seen that this material differs from that found at Gable Farm, Wraxall, in terms of the colour and nature of the till matrix, and also in the lithologies of the clasts. That at Gable Farm contained a large percentage of Carboniferous Limestone (presumably from the Failand Ridge), in a matrix composed largely of redeposited Keuper Marl. The locally derived material at Ham Green was Pennant Sandstone and Quartzite, along with a greater amount of far travelled material, and a matrix which varied in colour.

Before a more detailed discussion of the origin of these tills can be made, it is necessary to examine the evidence found from the final fieldwork area around Sheepway, three miles north of Pill.

9. THE PORTBURY - SHEEPWAY AREA

This site lies on the west of the mouth of the River Avon, at its confluence with the River Severn. The area is predominantly flat, low ground, north of the Failand Ridge.

To the southwest is a spear-shaped area of land between the Failand and Portishead ridges, from which the valley derived its name, the Vale of Gordano. Whilst the southern end of the Vale of Gordano is of particular Quaternary significance for the Zone III peat, developed behind a sand bar (Jeffries, Willis and Yemm, 1968), this study will only consider the "gravel" deposits in the Sheepway area, at the northeast end of the Vale.

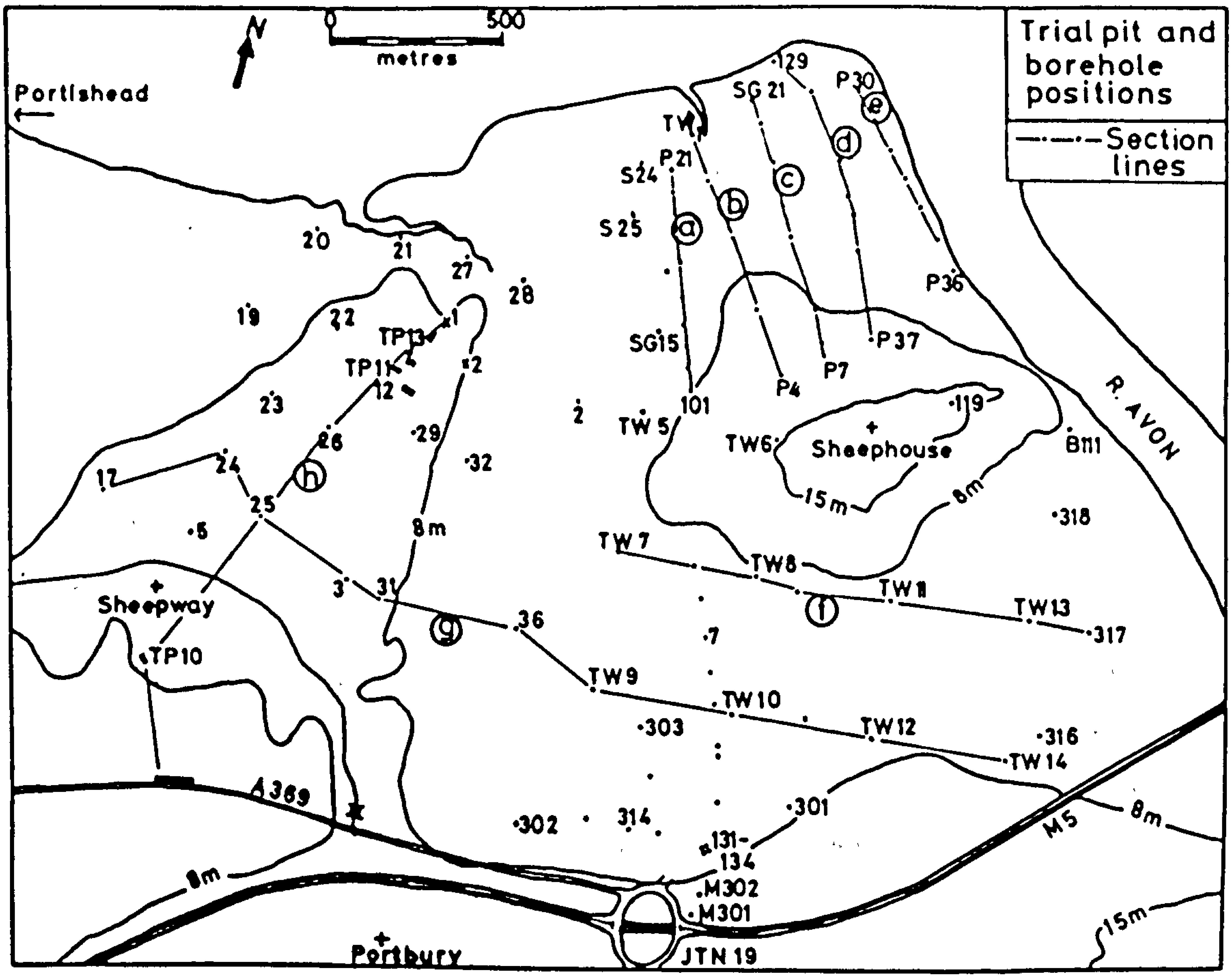
Two higher points of land rise above the generally flat terrain, north of Sheepway and at Sheephouse. These result from local relief highs left in the Keuper Marl bedrock, covered with a drape of sand and gravel deposits. The origin and nature of these deposits was investigated in the present study. The area has already been the subject of a paper by Hawkins (1967), in which he used borehole data obtained prior to the construction of the West Dock scheme to analyse the spatial distribution and nature of the deposits. He divided the gravels into three groups :

1) Those around +9m O.D., found on top of the Sheepway and Sheephouse rises.
2) Those in the area of the West Dock scheme (later Royal Portbury Dock) at around -3m O.D.
3) Those lying in a sub-alluvial valley running NW-SE between the two rises at around +1m O.D.

Since the publication of this paper much more information has become available, namely a further site investigation programme over the site of the Royal Portbury Dock and its access route (completed 1975), and the building of the M5 motorway to the south of this.

To complement the written data the present author undertook fieldwork around Sheepway village, including the recording of two permanent and one temporary exposure (Exp. 1 and 2, and the A369 ditch) and the

A



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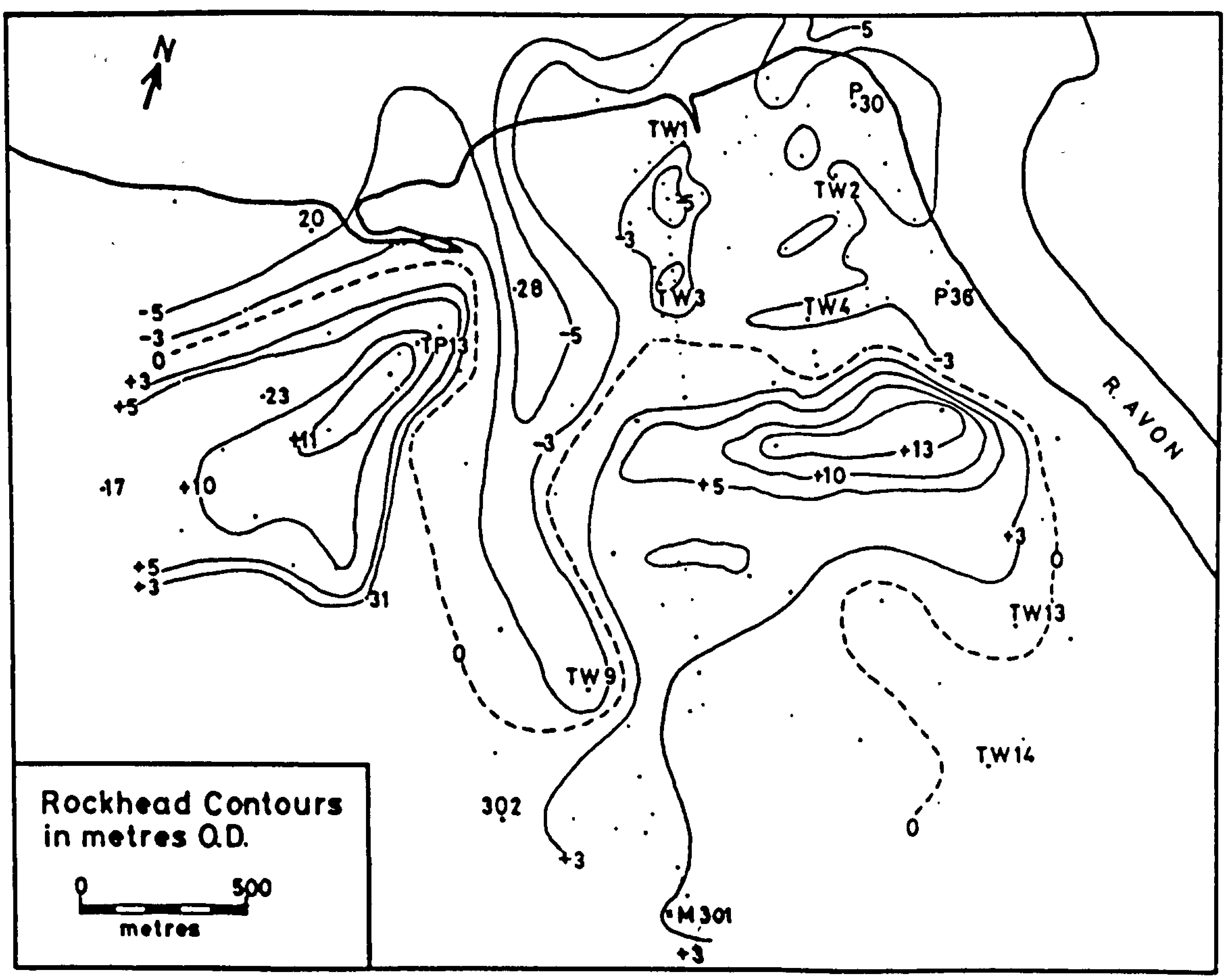


Figure 4.28 : The Portbury - Sheepway area

excavation of four trial pits (TPs 10-13). The positions of trial pits and boreholes are shown on Fig. 4.28a. These will now be discussed.

a) <u>THE A369 DITCH EXPOSURE</u> :

In the late autumn of 1983 the drainage ditch alongside the "Portbury Hundred", a section of the A369 Bristol to Portishead road, was cleared of vegetation and partially recut by the local council (Fig. 4.28). The result of this was an exposure of sands and gravels, running approximately E/W, for a length of around 100m. The ditch was 1.5m deep from the top surface at c. 6.2m O.D. with Flandrian alluvium forming a blanket of between 0.4 to 0.7m thick over the sands and gravels below. The deposits continued beneath the water level and base of the ditch. Bedrock was not found at any point along the exposure, although it was noted directly below the alluvium further to the east.

The main part of the exposure, some 80m in length, was recorded in detail by means of a section drawing and written description, while some 40 photographs and 11 particle size samples were taken. The western end of the section was taken as the zero point and all measurements relate to this.

Fig. 4.29 shows a section drawing of the ditch and from this the overall succession can be seen :

7) Topsoil
6b) Flandrian alluvium
6a) Older alluvium
5) Coversands
4) Red and orange glacial till
3) Muddy gravels
2) Sandy gravels
1) Grey green glacial till

Figure 4.29 : A369 ditch section, Portbury

1) Grey green glacial till : (Photo 4.32 and Fig. 4.30)

From 57 to 80m along the base of the ditch, a grey green muddy, medium to coarse gravel up to 0.4m thick, was exposed intermittently by hand clearing (Sample A369/7). This muddy gravel had some red brown patches, sandy areas, and locally some iron staining. The pebbles were mainly rounded, weathered limestones, with some sandstones, angular flints and cherts. The whole deposit gave the appearance of a patchwork of sandy areas, clay rich pockets, rotted limestone cobbles, and intercalated muddy gravel. Such a deposit strongly suggests a glacial origin, giving this haphazard mix of materials.

2) Sandy gravels : (Photo 4.33)

In the western 44m, along the base of the ditch, was found up to 0.6m of orange yellow sandy, predominantly medium grain size, gravels (Samples A369/3 and A369/4; Fig. 4.29). The pebbles were subrounded to rounded and a mixture of local sandstones and limestones. From 14 to 17m, a sand lens was noted within these gravels, significantly showing finer sand at the base and becoming coarser upwards, while intercalated with these was a lens of fine gravel. Between 41 to 50m another sand lens showed the same coarsening upwards (Sample A369/5; Photo 4.34). There were also some small clay patches and black stained laminae within the sand.

Some large cobbles, mainly of Jurassic limestone, were found sporadically set within the gravels, especially towards the top surface, e.g. from 22 to 28m, and at 41m. The gravels were generally unsorted, with little or no horizontal differentiation or bedding planes visible.

3) Muddy gravels : (Photo 4.32)

From 44 to 80m, mainly lying over the sandy gravels and partially over the grey green glacial till, was a deposit of orange to red brown muddy sand and gravel (Sample A369/9). Within this were many patches of grey green clayey gravel, or very sandy material. Often the pebbles (especially those of limestone) were rotted and showed a lithified core surrounded by a margin of decayed material, partially incorporated into the enclosing matrix. Some of the sandier areas were found to consist

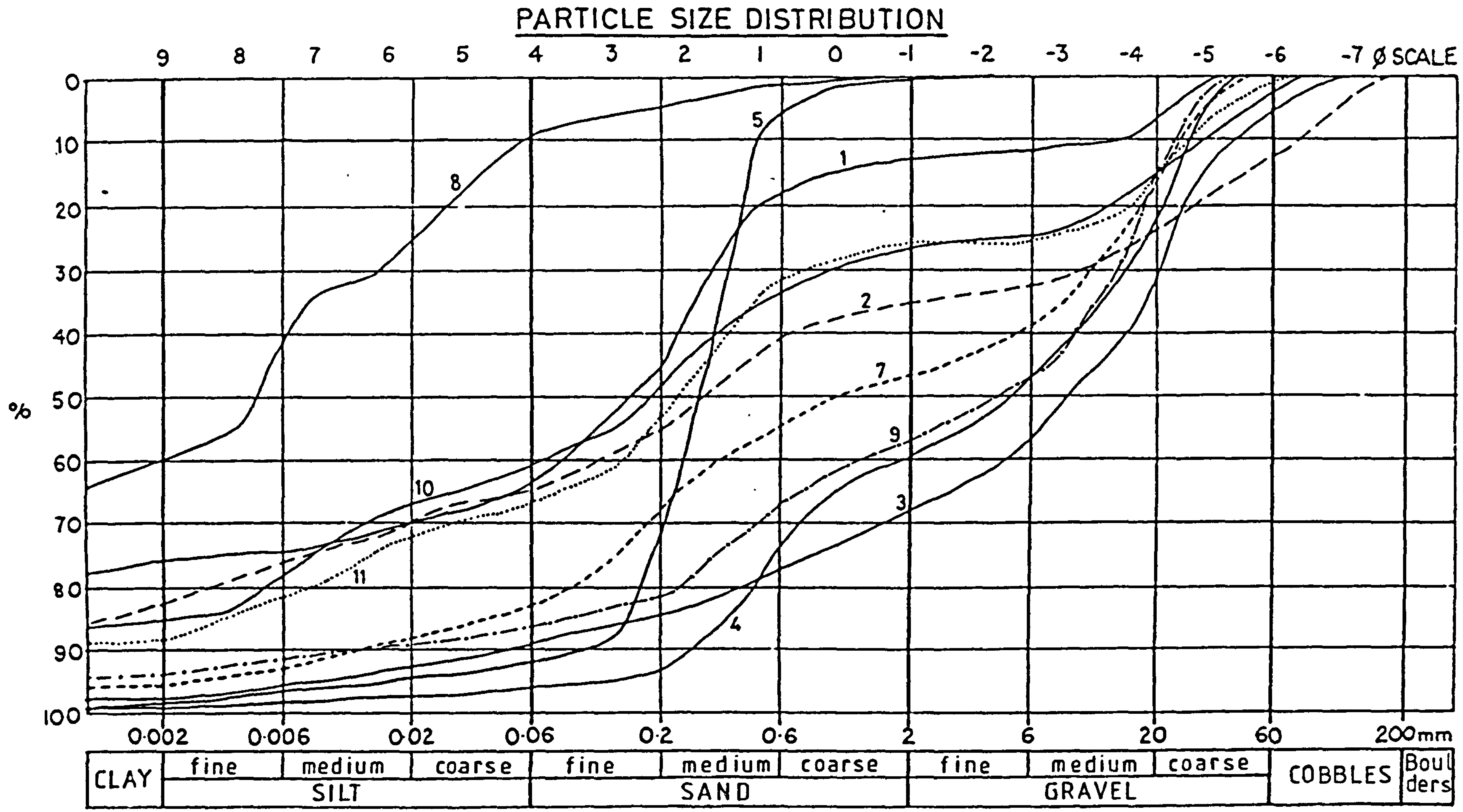


Figure 4.30 : Particle size results, A369 ditch, Portbury

of the weathered and decayed remains of coarse green sandstone fragments. At 54m the deposit included much pitted and angular flint and chert, along with both rounded and angular sandstones, Carboniferous and some Jurassic limestones.

When examined in the field this deposit closely resembled, and may well be, a Devensian till, although its lower mud content and greater number of gravel clasts compared with Layer 1 below separates it from the latter.

4) Dark red brown and orange glacial till :

Blanketing the sandy gravels and muddy gravels to the west, and the grey green till to the east, were deposits of dark red brown and orange muddy sands with some fine to medium gravel (Sample A369/10). To the east this material included some medium to coarse gravel and occasional cobbles (Sample A369/2 and Photo 4.33). Several boulders of local sandstone found between 43-45m may belong to this deposit, but it was not clear whether they were in situ.

Some areas of the deposit were quite organic rich, in particular around 37m where the whole deposit became a dark grey due to the colour of its silt and clay matrix (Sample A369/1 and Photo 4.34).

Between 12-30m a level of more orange muddy gravel was interfingered with the dark red brown material. Colour was the only visible distinction between these two deposits.

The dark red brown muddy gravel formed the infill of two wedge features discussed below (Sample A369/11 and Photo 4.35).

5) Coversands :

In certain parts of the ditch section, the dark red brown material discussed above is relatively stone free, consisting of dark red clayey silt. This deposit achieves its maximum thickness towards the western end of the section, where it lies between the sandy gravel and the alluvium, and again at the eastern end, where it is found between the grey green glacial till and the alluvium. It forms a thin layer over the red brown glacial till in the middle part of the section. This material is however extremely difficult to distinguish from the matrix of the dark red brown till below, and it may be that the upper material is only a stone-free variant of the till. Its interpretation will be discussed further below.

6a) "Older alluvium" :

Over Layer 5 was a thickness of dark grey brown silty clay. This became more orange brown east of the 36m mark. In parts it included some medium gravel similar to that found below. It was interpreted as alluvium, previous to the Flandrian material above. In the west of the section it was very close in nature and colour to the Flandrian above. To the east however it ranged from orange to red brown and included pebbles from the layers below. As such it is possibly an example of the primary alluvial deposition over the area, infiltrating with the previous deposits.

6b) Flandrian alluvium :

Below the topsoil for between 0.4-0.7m was a layer of light blue grey, very silty clay (Sample A369/8, Fig. 4.29). This completely blanketed all previous deposits. On noting its nature and position here, and with reference to other locations, this was recognised as the Flandrian alluvium.

7) Topsoil :

This consisted of 0.1-0.2m of medium to dark brown soil.

Interpretation of the deposits :

Layer 1 : Grey green glacial till :

The unsorted haphazardly deposited nature of this material is similar to that found at Wraxall TP30 and at Ham Green, except that it is of a finer mean grain size, the particle size results giving only 18% mud. As such, its poor sorting suggests a glacial origin, but the material may have been redeposited partially by running water.

Layer 2 : Sandy gravels :

This material is the best sorted amongst the gravels, with less than 10% mud and 60-68% gravel. The pebbles are mainly subrounded and of very local lithology. The inclusion of moderately sorted sand lenses confirms that this is an example of a fluviatile sand and gravel sequence.

Layer 3 : Muddy gravels :

The muddy gravel lying over Layer 1, along the eastern end of the section may be another example of glacial till, partially resorted by fluvial action. It also gives evidence of severe weathering in the rotted and pitted gravel fragments.

Layers 4 & 5 : Red and orange glacial tills and coversands :

It has already been noted that the dark red brown muddy matrix of this deposit is extremely difficult to distinguish from the material considered to be coversands, which overlies this glacial till. Two possible explanations for the deposits exist :

a) In a periglacial environment, strong winds sweeping over an unvegetated area of extreme cold and aridity entrained particles of clay and silt which were redeposited as a thick layer of aeolian coversands over the fluvioglacial sands and gravels, muddy gravels, and the grey green glacial till. Some downward infiltration of the coversands into the upper layers of the gravels occurred, perhaps after interstitial ice had melted. Cryoturbation further developed this process of incorporation with the deposits below. The later submergence of the area and deposition of the Flandrian alluvium would have continued the leaching of fines from the coversands.
Hence Layers 4 and 5 consist of the same deposit of dark red coversands, which has, in places, been incorporated with earlier deposited gravelly materials.

b) The dark red brown muddy gravel is a deposit left by ice. The matrix of this till is mainly derived from the local Keuper Marl, and it contains gravel clasts of both local limestones and sandstones, and further travelled flints and cherts.

As the ice retreated, leaving this material behind, the area suffered periglacial conditions. Winds of up to 30 kms per hour, blowing outwards from the ice sheets, caused the transport and deposition of the clay and silt matrix of these tills. This formed a blanket of coversands, closely resembling the matrix of the tills from which it was largely derived.

The subsequent submergence of the area and deposition of the Flandrian alluvium may have removed some of the coversands.

The second possibility is considered by the author to be the more likely explanation. Vink (1949) recorded the presence of loess/coversands material in the Vale of Gordano, and Avery (1955) and Findlay (1965) have discussed their contribution to the soils of the district. Similar gravelly earth or sandy loams have been noted elsewhere in the region (Kidson, 1971; Gilbertson, 1974). The lithological and textural characteristics of the deposits will be discussed in Chapter 5.

Recently Gilbertson and Hawkins (1983) recorded ice wedges infilled by gravels in a sandy clay matrix, found during the construction of the M5 motorway bridge at Avonmouth. This wedge infill was thought to be a till remnant, and both the wedge feature and its contained deposit were considered to be previous to the deposition of a loamy coversand which overlay both.

Similar permafrost phenomena were recorded in the A369 ditch section.

Wedge features : (Photo 4.39)

These occur in the section at 14 and 28m from the west end, where the dark red brown till and coversands material infills V-shaped features within the sandy gravels.

The feature at 14m had a basal width of 120mm, spreading to 430mm at the widest point, and with an observed height of 650mm. On either side of the feature the gravels were undisturbed, with a coarse sand horizon continuing both to the east and west. Within the feature were two types of material : The lower deposit filling the base and sides of the wedge, was of red brown clayey silt with some gravel, within which was a V-shaped area of red brown silty clay, 240mm wide at the top, and with its "point" 250mm above the base of the ditch.

In view of the presence of a land drain, about 0.5m west of this wedge, careful consideration was given to the possibility that the ice wedge was in some way an associated feature. However, undisturbed sandy gravel and coversands existed between the pipe trench and the wedge, showing the features to be genetically unrelated.

At 28m along the ditch, another less obvious wedge exists. This measured only 250mm at the top, 120mm at the base, and only 300m was exposed above the water level and the base of the ditch. On either side was the orange very sandy gravels, while the infilled material was the dark red brown silty clay and gravel as found in the first feature.

These wedges are known to form under cold conditions where water, trapped within contracted, loose sediments, forms ice, increasing in volume and expanding the openings. With an amelioration in temperature, the voids would become infilled by meltwater deposits, or by airborne silty sands, i.e. coversands. Some infilling by the material in which the wedge was developed would also be expected.

Wedges are known to grow actively where the mean annual temperature is less than -6^{o}C (Pewe, 1966; Gruhn and Bryan, 1969), hence these wedges in the A369 ditch section are evidence that permafrost conditions were in existence at least after the deposition of the sandy gravels, and just prior to the infilling of the wedges.

The wedge at 14m in particular shows a complex period of periglacial conditions. The wedge is cut into the sandy gravels and appears to be infilled by the dark red till. The latter however has also been affected by permafrost, since it it is itself cut by a V-shape which is infilled by the coversands material. The following sequence of formation is suggested :

5) Amelioration in climate resulting in a melt. This caused the glacial till material to slump into the fissure within the sandy gravels, and the coversands into the resultant depression in the glacial till material.

4) The deposition of coversands over the area, during periglacial conditions.

3) Permafrost causing the freezing of meltwater in contraction cracks within the frozen sandy gravels and the growth of interstitial ice in the glacial tills.

2) Glaciation of the area and the deposition of the dark red and orange glacial till.

1) Deposition of the fluvioglacial sandy gravels.

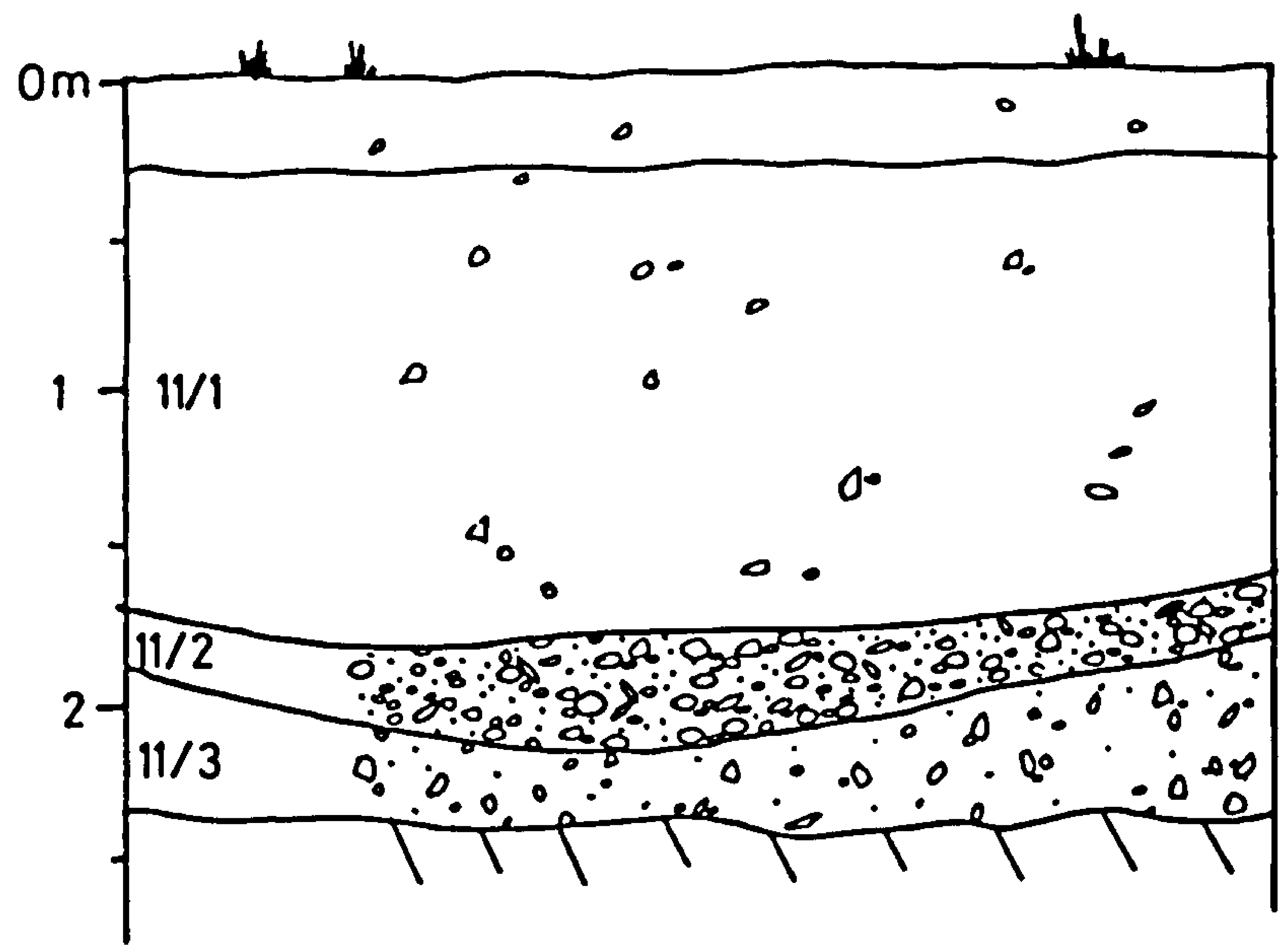
b) SHEEPWAY, TPs 11-13 :

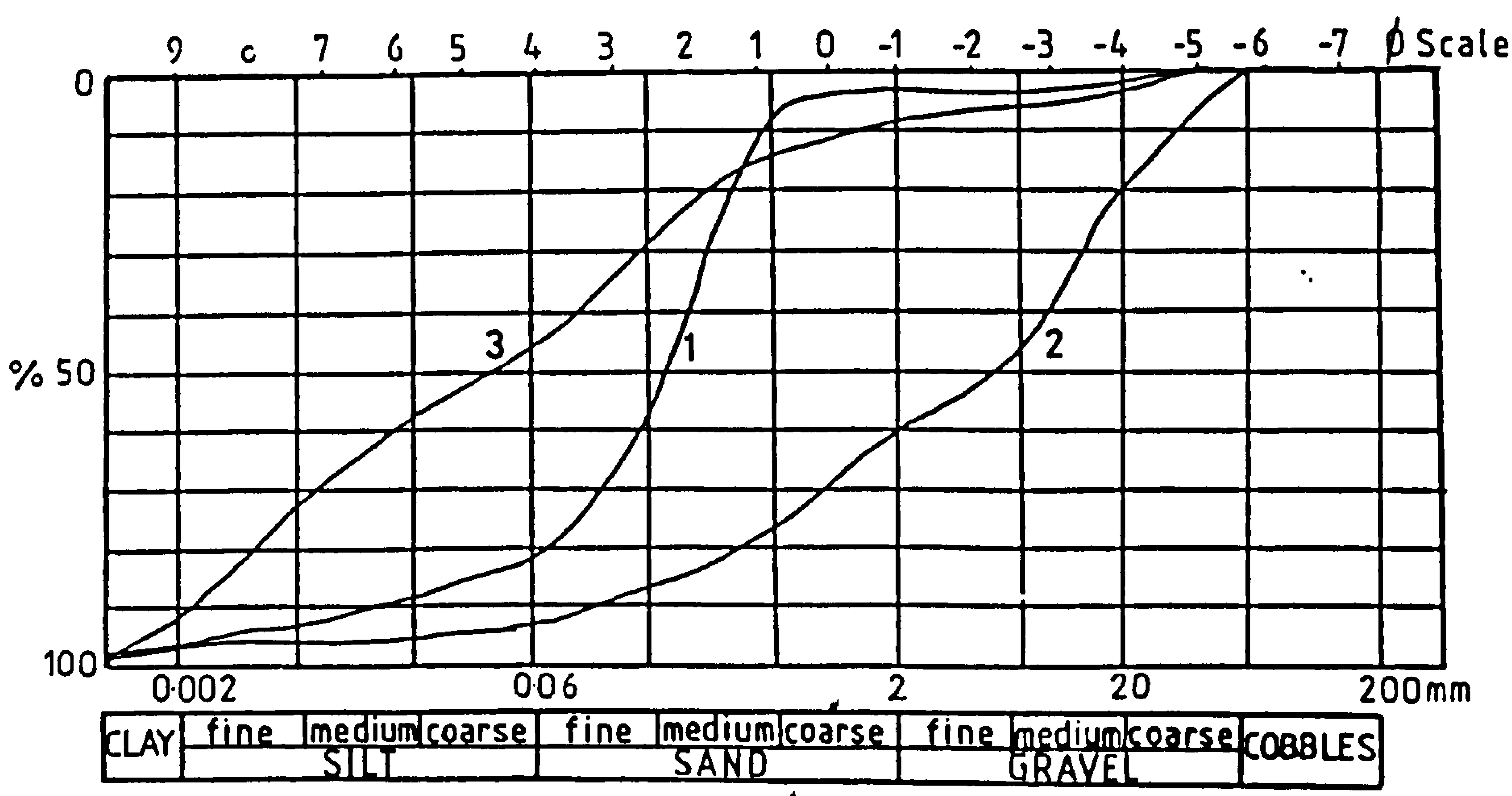
These were dug on the Sheepway rise to provide both sections and samples of the deposits which would complement the documentary evidence provided by the Portbury Borehole Series (Fig. 4.28).

TP11 : (Fig. 4.31 and 4.34)

The first pit, at 13.7m O.D., showed 2.3m of deposit over the Keuper Marl bedrock. The lowest 0.5m consisted of dark red silt and sand with some fine to medium gravel. This resembled the Keuper Marl below, though here it was a darker, and slightly more purply colour, and contained some orange and black flecks, of iron and manganese. The gravel was very weathered and showed signs of the initial stages of decalcification in the decayed margins of some of the limestone pebbles. Thus it is not interpreted as simply the upper surface of the in situ Marl with some incorporated gravel, but rather a deposit made up of a gravel in a Marl bedrock matrix which has been weathered, transported and redeposited.

Sheepway TP11





Particle Size Distribution

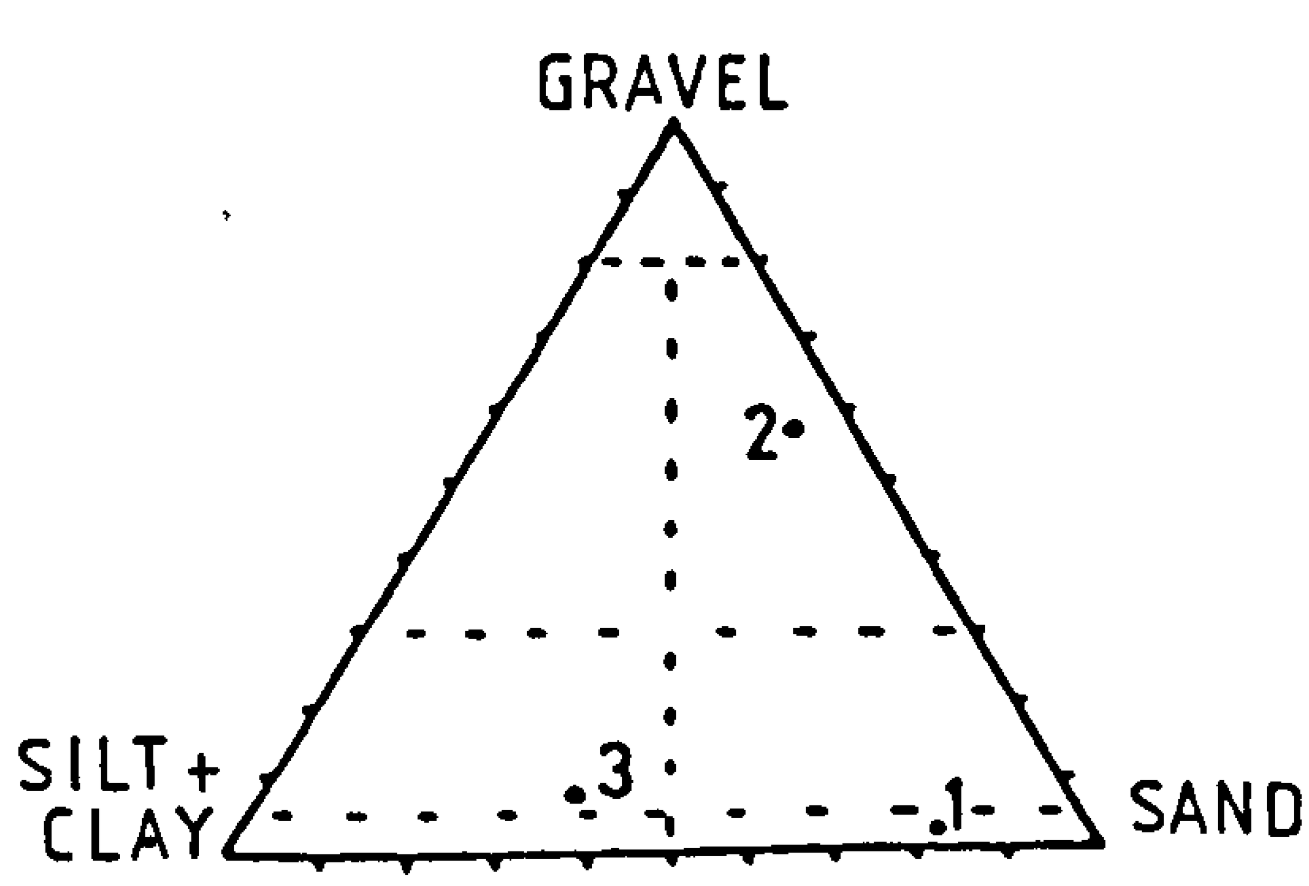


Figure 4.31 :

Field descriptions and particle size results, TP11, Sheepway

Above this, and seen in the pit section as a lens shape, was 0.1-0.4m of very sandy, fine to coarse, subrounded gravel with some mud. Over this again was 1.5m of dark red to brown, silty sand with some gravel. The sand made up 80% of the deposit, with 52% of medium grain size. This was covered by 0.25m of black ashy topsoil.

The interpretation of this trial pit proves to be very similar to the deposits found in the A369 ditch. At TP11 the preserved sedimentary succession is :

7) topsoil
5) coversands
2) sandy gravel (Numbering as the A369 Layers)
1) possible glacial till

Keuper Marl

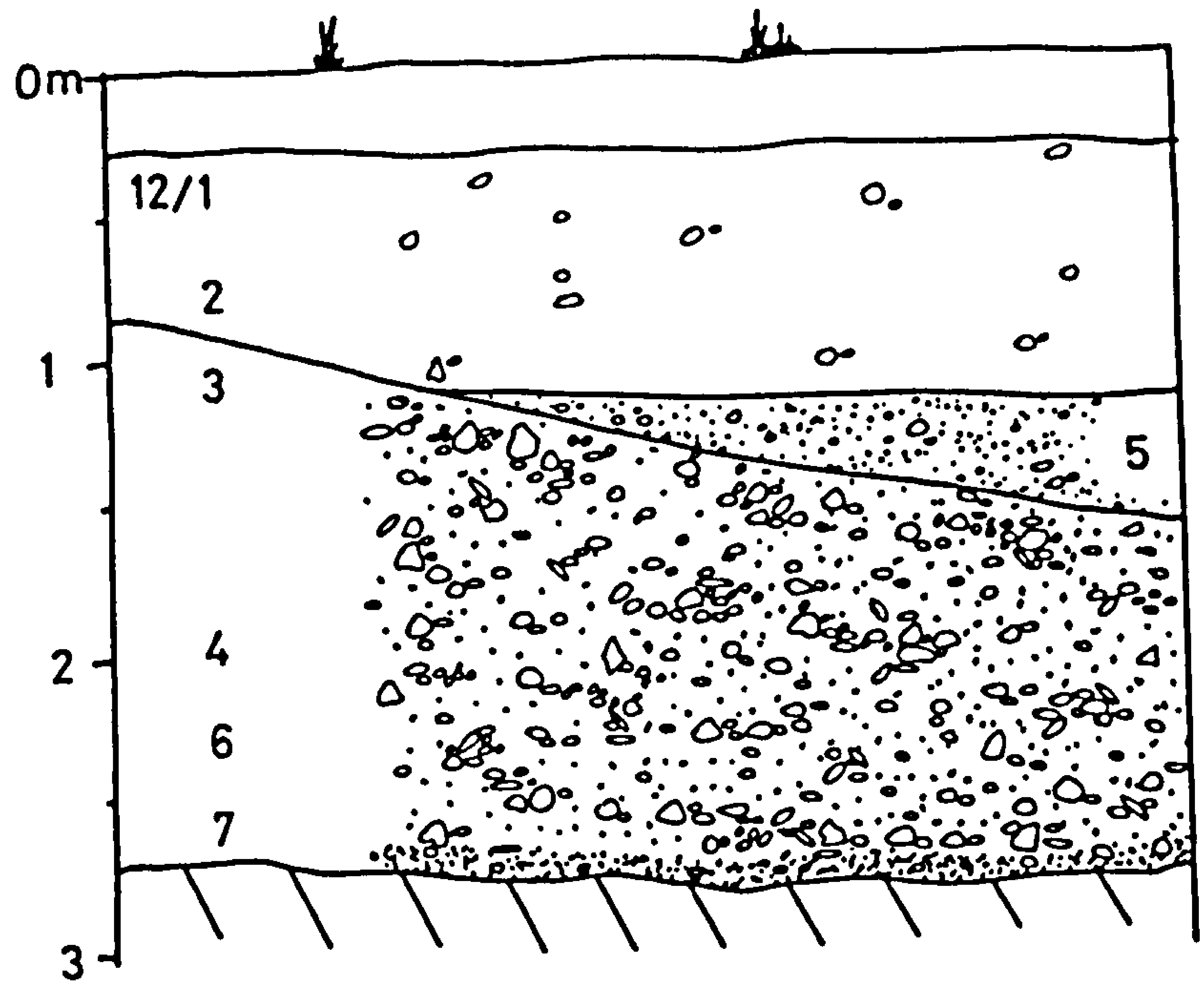
As will be seen, the other trial pits gave a similar picture.

TP12 : (Fig. 4.32 and 4.34, Photo 4.36)

This lay 30m east of TP11 at 13.2m O.D. Again the Marl bedrock was at 2.7m depth, though here the sandy gravel, with a grey gravelly sandy mud at its base, lay directly over the Marl (Sample 12/7).

This main sandy gravel reached a maximum thickness of 1.85m and included lenses of more muddy gravel with larger pebbles (Sample 4). Overall the deposit grades from 73% gravel and 2% mud (Sample 6), through 61% gravel and 20% mud (Sample 4), to 25% gravel and 41% mud at the contact with the layer above (Sample 3). This is also reflected in a decrease in the sorting since Sample 3, in spite of having a finer mean grain size than the lower samples, contains gravel up to -5ϕ. The highest observed point of this gravel lies on the south side of the trial pit section, while on the north it dips down and is covered to a depth of 0.4m by a layer of gravelly very muddy sand. This continues the fining upwards sequence.

Sheepway TP 12



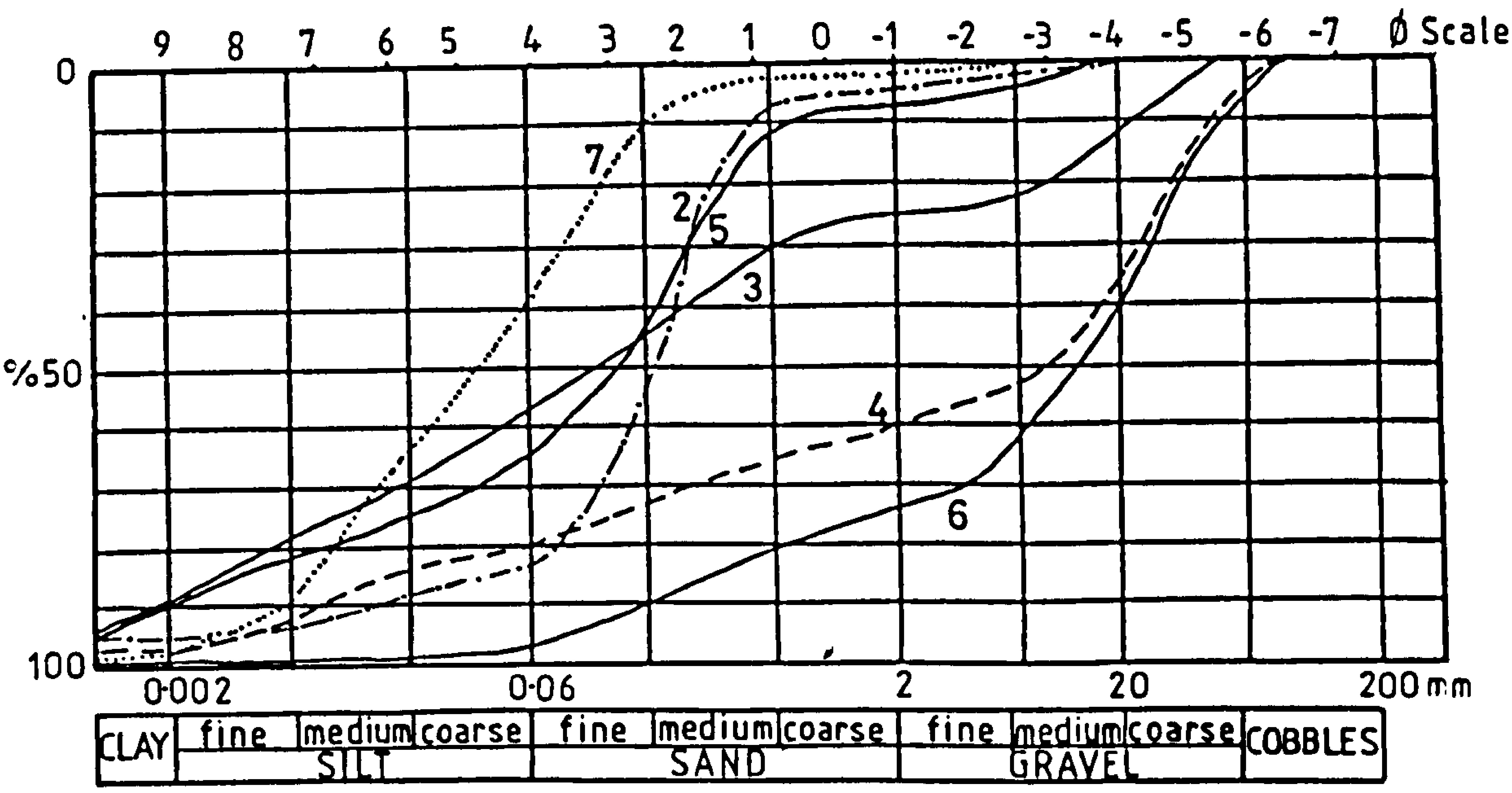
Grey brown topsoil

Orange brown becoming red brown gravelly muddy SAND

Gravelly, very muddy SAND lens

Fine to medium GRAVEL in red brown clayey silt
Muddy, sandy GRAVEL
Fine to medium GRAVEL with sand
Grey, slightly gravelly, sandy MUD lens

Keuper Marl



Particle Size Distribution

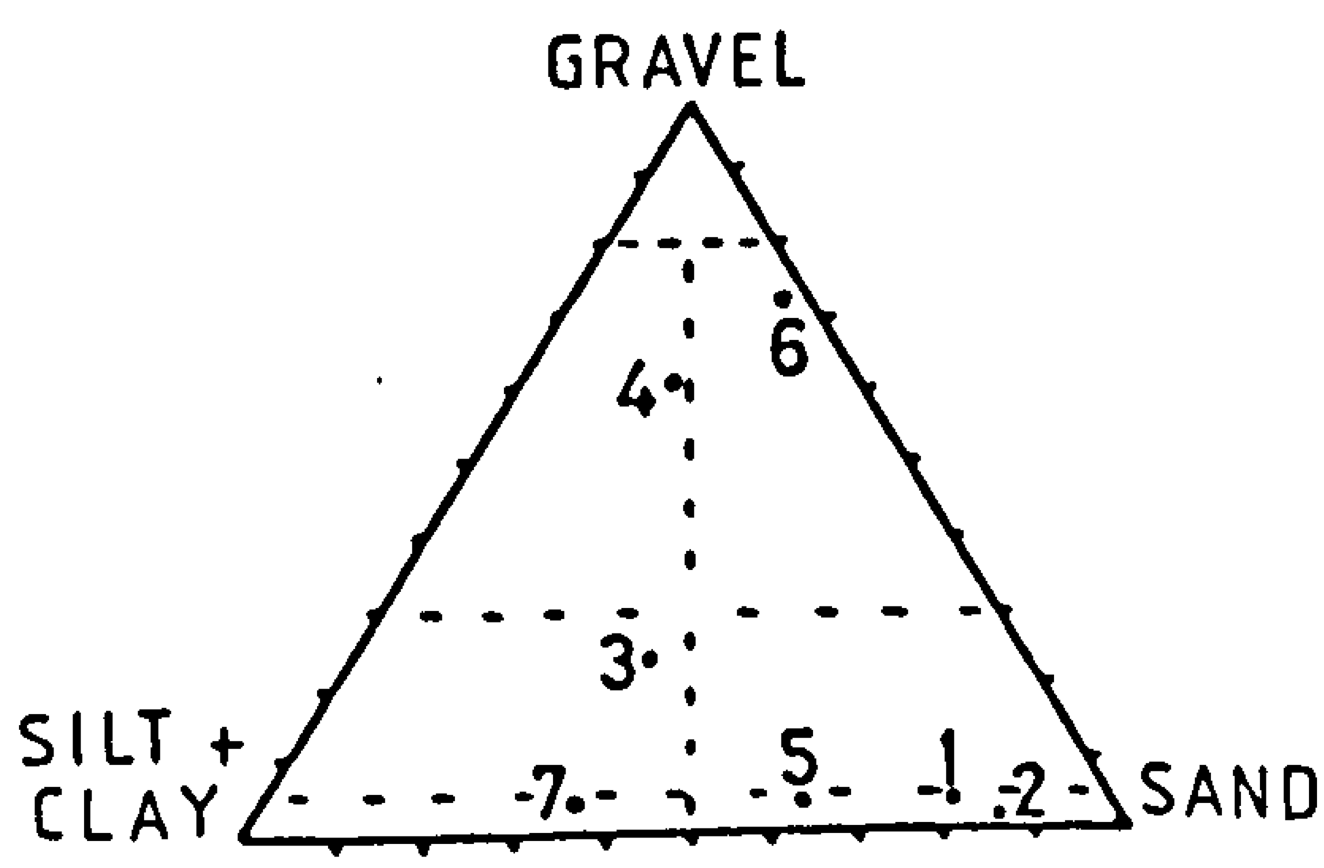


Figure 4.32 :

Field descriptions and particle size results, TP12, Sheepway

Over both these layers is the same blanket of up to 0.85m of orange brown to red brown gravelly muddy sand that was seen in TP11 forming the coversands. Over this was 0.25m thick of grey brown silty topsoil.

TP13 : (Fig. 4.33 and 4.34 and Photo 4.37)

This pit was placed to the north of TPs 11 and 12 to provide an intermediate sampling point between them and Exposures 1 and 2 further to the north and east. From a ground surface at 12.8m O.D. the Marl was encountered at 2m. As in TP12 this was covered directly by 1-1.5m of the sandy gravel, again with a very sandy base, a slightly coarser layer in the centre, and a sandy top. Overall it was less muddy than in TP12 and thus a more sandy looser material. Again the orange brown occasionally gravelly muddy sand covered the main gravel for 0.25-0.8m depth, below the topsoil.

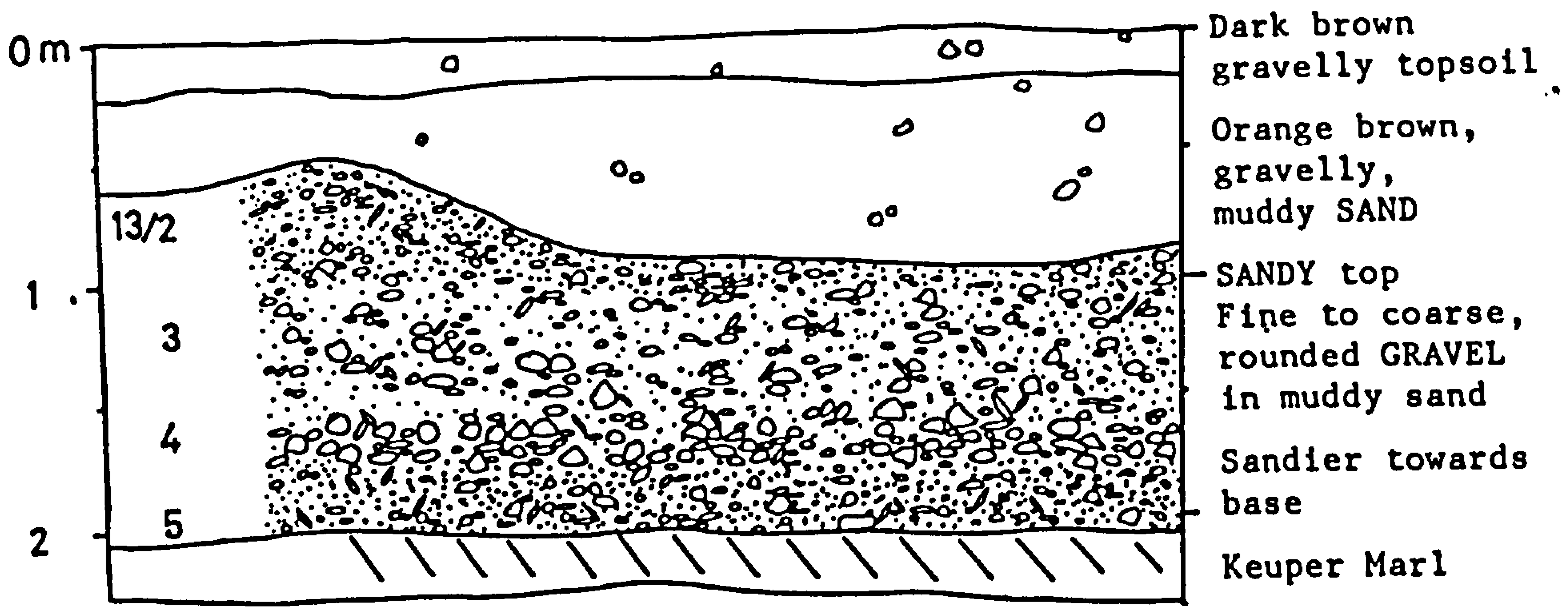
Fig. 4.34 shows the particle size curves of the samples from TPs 11-13. They fall into three sedimentary groups :

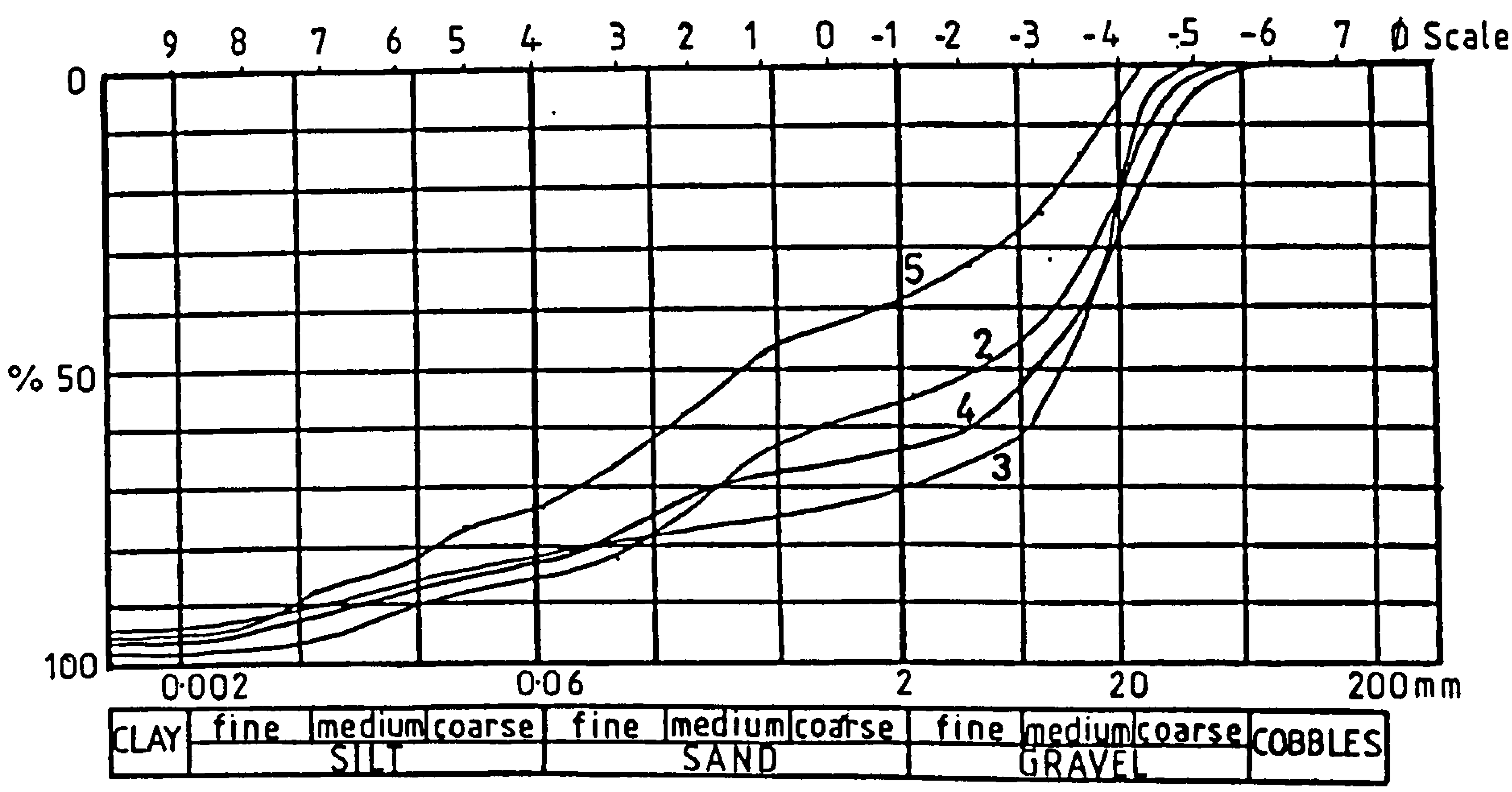
a) The gravels : Samples 11/2, 12/4 and 6, 13/2, 3 and 4 have between 55-75% gravel and less than 20% silt and clay. They show a similar size distribution to the sandy gravels from the A369 ditch and are likely to be a fluvioglacial outwash deposit.

b) The gravelly muds : Samples 11/3, 12/3 and 12/5 have between 8-25% mud and 45-65% silt and clay.
TP 11/3 lies beneath the sandy gravel and over the Keuper Marl. It may represent a remnant of till but is more likely a pocket of redeposited Marl with some incorporated gravel.
Sample 12/5 is a poorly sorted sand and can be interpreted as an overbank flood deposit or a continuation of the fining upwards sequence of the sandy gravels below, with Sample 12/3 the more gravelly deposit, an intermediate stage between the two.

c) The muddy sands : Samples 11/1 and 12/2 have 78% fine to medium sand and 18% mud. Their appearance, position in the succession, and particle size distribution suggests they are "pure" coversands

Sheepway TP13





Particle Size Distribution

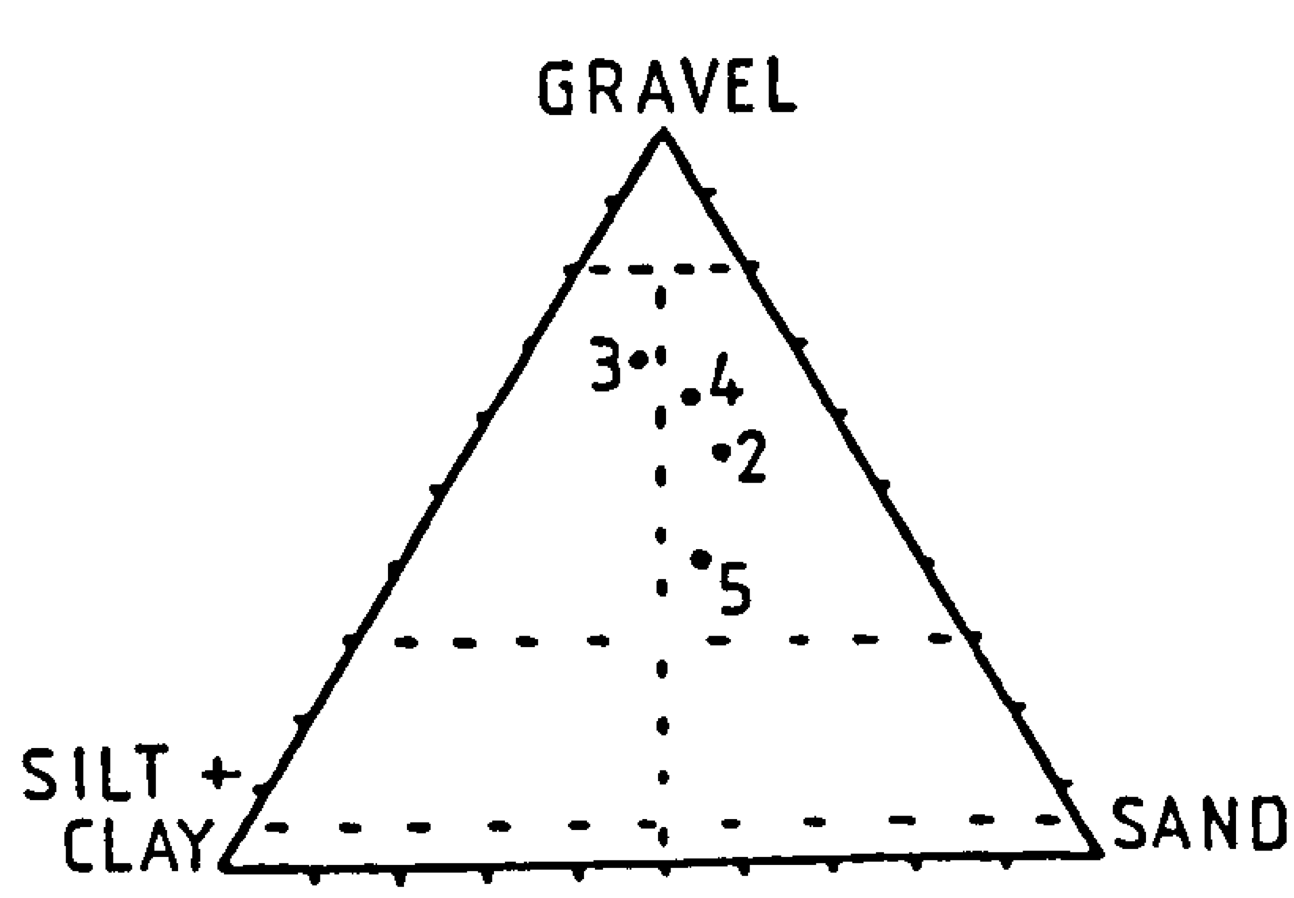


Figure 4.33 :

Field descriptions and particle size results, TP13, Sheepway

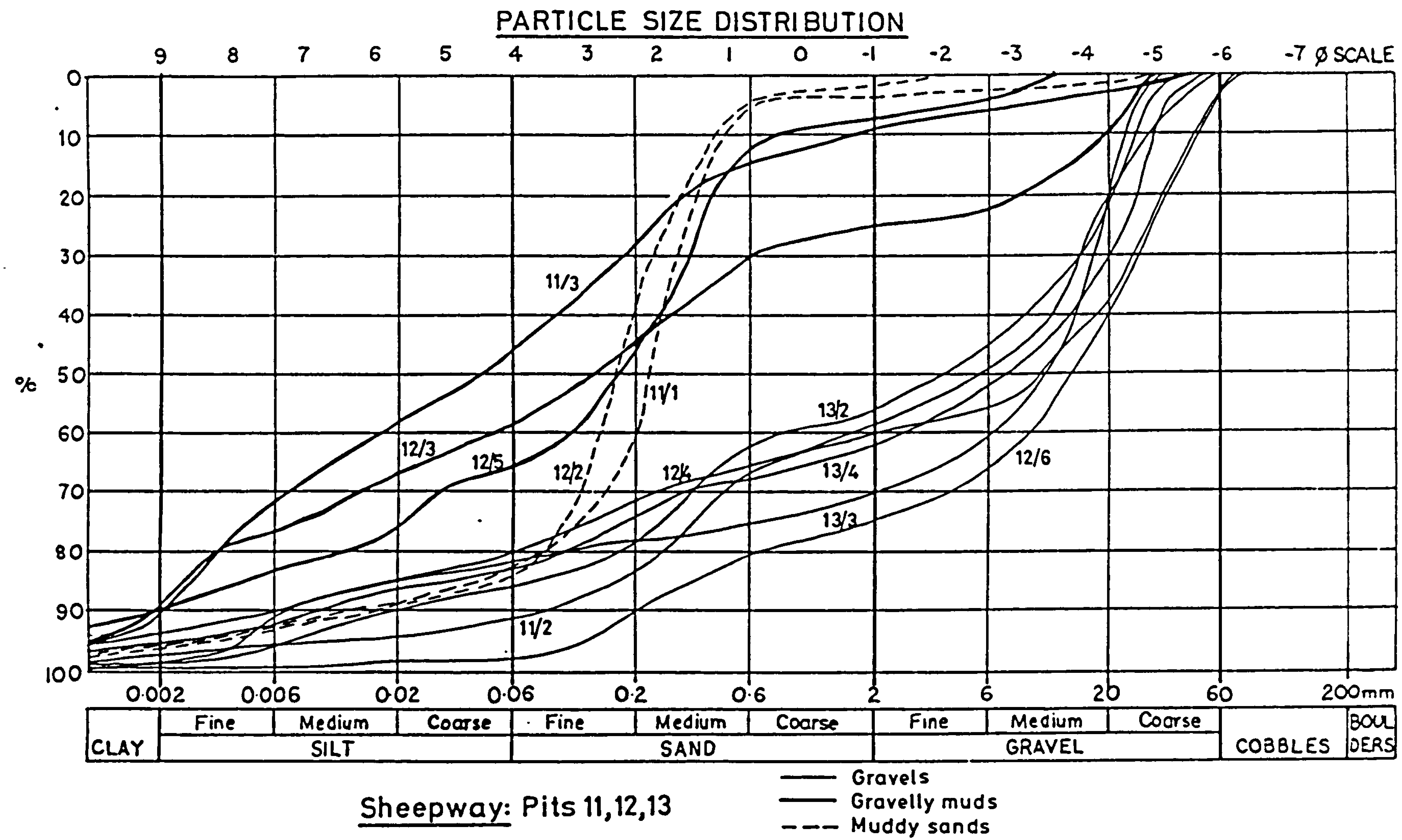


Figure 4.34 :

Particle size curves

material, without the incorporation of gravel size material as found in the A369 ditch.

c) <u>SHEEPWAY EXPOSURE 1</u> : (See Fig. 4.35)

This permanent exposure is found to the north of TP13, on the edge of a small "river cliff", formed by a meander in one of the many small streams draining the alluvial flats to the north of the Sheepway rise. To reveal the deposits more clearly and remove disturbed material, a section was dug by hand. This was a 1m wide vertical strip down from the ground surface (Photo 4.38).

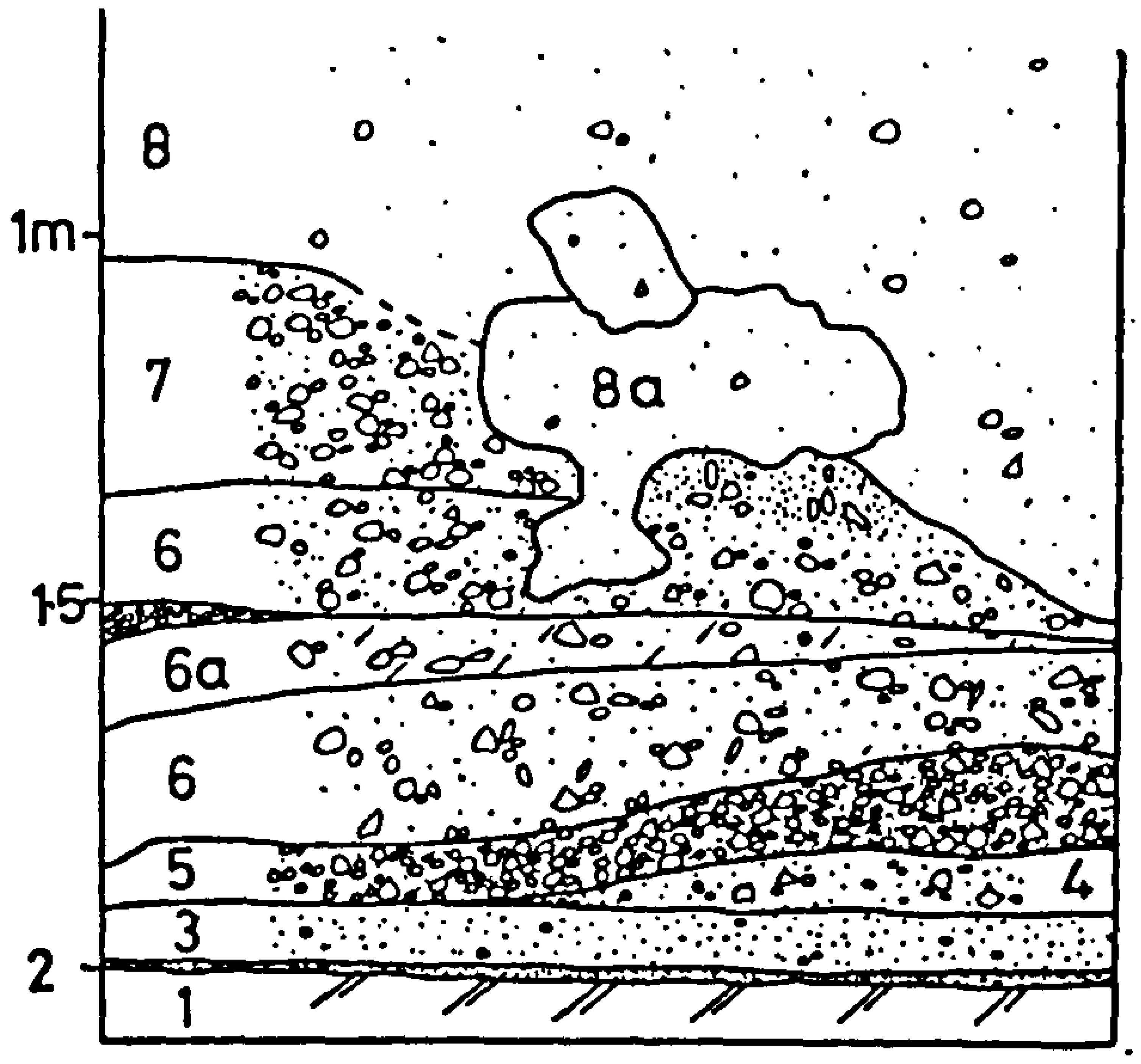
The Marl was encountered 2m from the surface at 11.07m O.D. Above this was up to 1m of gravel. Because of the small nature of the cleared section it was possible to examine the content of the gravel more closely than in the temporary and often unstable, deep sections of trial pits.

Over the bedrock was a medium sand layer only 20mm thick, covered in turn by c. 60mm of gravelly, muddy, medium to coarse sand (Layers 2 and 3). These are the equivalent of the sandy layers found in the same position in TPs 12 and 13. Over these the true gravels consist of a small lens of muddy sandy gravel (Layer 4) below a better sorted, dense, medium gravel (Layer 5). This latter was the best sorted deposit of the section and had a maximum thickness of 150mm, where it was draped over the muddy, sandy gravel on the west of the section. It thinned to 50mm on the east where it lay directly on top of the sands.

Above these, and forming the largest part of the exposed deposits, was some 0.5m of a more sandy, fine to medium gravel in a red brown muddy matrix (Layer 6). Within this was a more muddy band, a gravel lens and a gravelly muddy coarse sand layer at the top. Overall the deposit was of the same red brown colour.

At c. 0.7m above the Marl was a further layer of yellow brown medium to coarse sandy, coarse gravel (Layer 7). This formed the coarsest deposit of the section, with a mean grain size of -2.5ϕ (medium gravel). This layer however was confined to the east side of the exposure. Above it,

Sheepway Exposure 1



8. Dark brown gravelly topsoil
Dark brown gravelly topsoil

7. Medium to coarse GRAVEL in yellow brown muddy sand

6. Fine to coarse GRAVEL in red brown muddy sand

6a. More clay-rich band

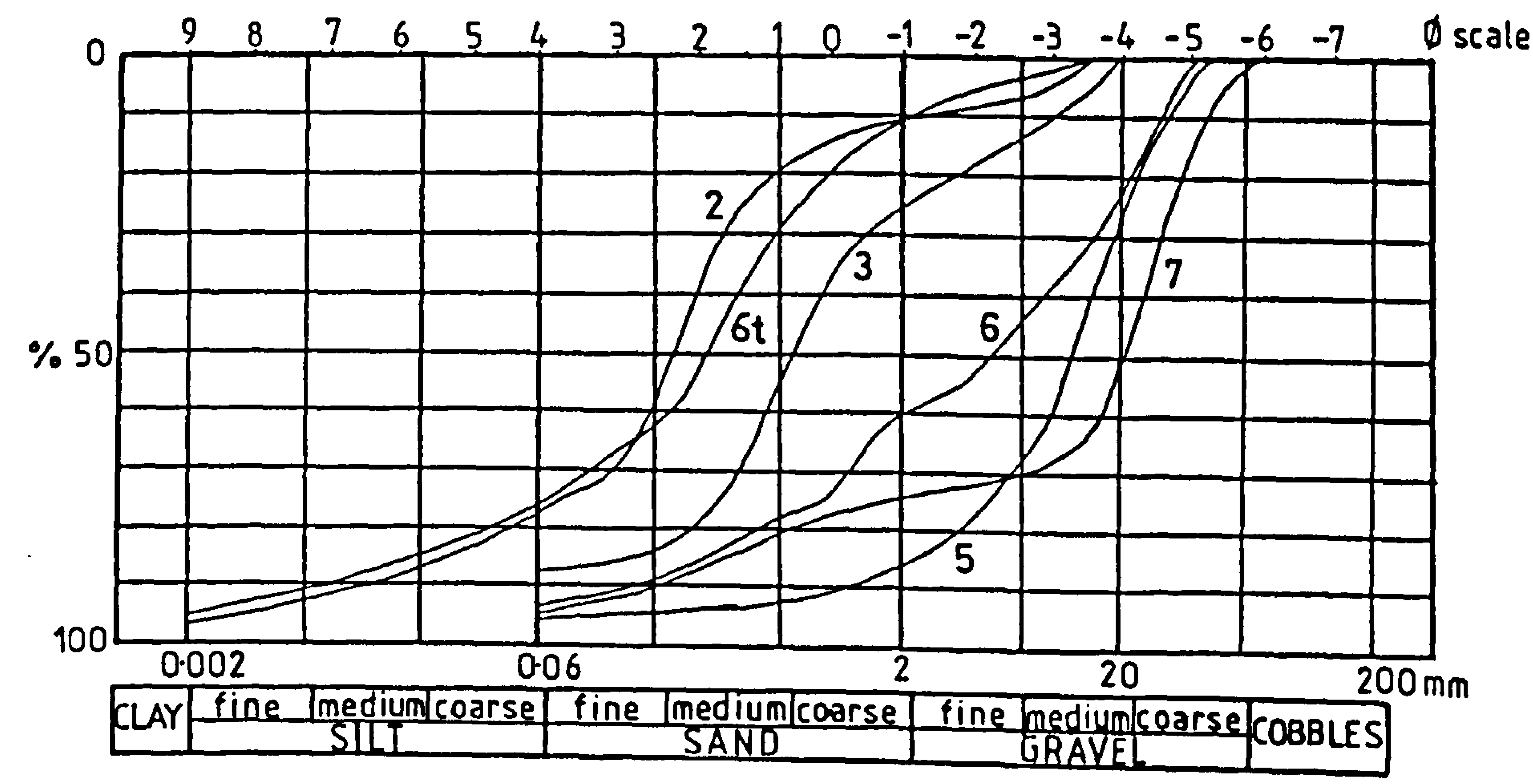
5. Medium GRAVEL with sand

4. Muddy sandy GRAVEL

3. Gravelly muddy coarse SAND

2. Coarse SAND lens

1. Keuper Marl



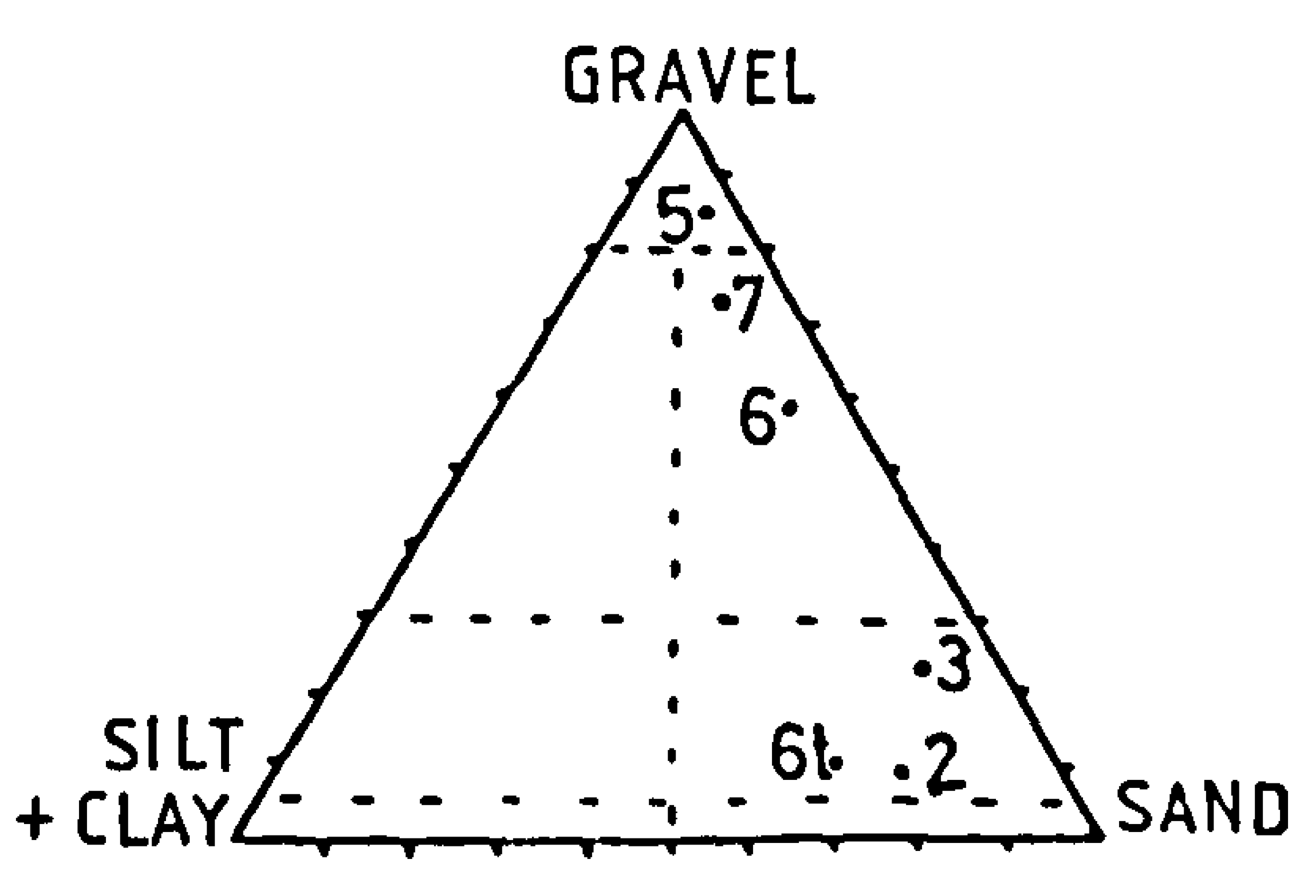


Figure 4.35 :

Field descriptions and particle size results, Exposure 1, Sheepway and over the redbrown gravel to the west, was the dark grey brown silty gravelly topsoil, which lay up to 1m thick. Within this was a patch of stone free soil, which rests partially on Layers 6 and 7. This protruded down into Layer 6 at one point and although it has not the classic wedge shape found, for instance, in the A369 ditch, it may be of similar origin. The nature of the exposure, on the steep slope of the stream section, suggests the wedge feature may have resulted from some instability and movement in the past. However, as there is a level of vertically set pebbles, below this feature, and just above Layer 6 (Photo 4.39), it is likely to have been a cryoturbation phenomenon.

Thus, comparing the exposure with TPs 11-13 and the A369 ditch, it is considered that here Layers 2 to 5 represent the sandy gravels, Layers 6 and 7 are equivalent to the muddy gravels, and the topsoil may to some extent incorporate some of the coversands material.

EXPOSURE 2 : (Fig. 4.28)

This is a small permanent exposure to the east of TP13, on the eastern edge of the Sheepway rise. Here a small ditch exposes some 0.75m of deposits, with 0.4m of dark brown sandy topsoil with some gravel, above 0.35m of red brown, muddy, fine to medium gravel. Beneath these is the Keuper Marl, which rises to the north, and,just 5m further along the ditch, is found directly below the topsoil. This thus represents an example of material on the periphery of the rise, where the gravel deposit is much diminished in thickness.

d) SHEEPWAY GATE FARM : (Fig. 4.28)

To determine the southern extent of the Sheepway deposits, fieldwork around Sheepway Gate Farm included some augering and the excavation by hand of a small trial pit. These provided evidence between the trial pits on the rise and the A369 ditch.

Fieldwalking delimited the gravel deposits using the abundance of pebbles found at the surface; this was further confirmed by augering which proved the Marl bedrock directly below the topsoil in the area where no gravel could be seen. Work then concentrated on the fields south east of the farm buildings and adjacent to the old railway line. Augering revealed the following stratigraphy :

4) Medium brown topsoil, 0.1-0.2m
3) Orange brown sandy subsoil, 0.1-0.2m
2) Small, local lens of gravelly sand, 0.1m
1) Red and occasionally green, clayey silt (Marl), top surface between 0.2-0.5m depth.

TP10 : (Fig. 4.28)

In order to obtain samples of the gravel deposit, a small pit was dug just north of the railway line at a height of 8m O.D.. This revealed 0.3m of dark brown topsoil over an orange brown sandy subsoil with some gravel, which consisted mainly of medium sized subrounded sands and occasional Jurassic limestones with some angular flints and cherts. Between 0.5-0.7m depth the top of the Keuper Marl was encountered. This pit confirmed the succession found during augering. Here, the orange brown sandy subsoil, which represents the coversands, does not overlie any substantial sandy gravel layer as was seen elsewhere.

It seems likely that the coarse gravel of the coversands are remnants of a shallow layer of glacial till, possibly outwashed or soliflucted, on the periphery of the sandy gravels.

e) THE PORTBURY BOREHOLES :

The original planning of the new Portbury Dock required the drilling of some 33 boreholes as part of the site investigations. The first proposed site, between the two higher areas of ground, was later rejected in favour of that of the present Royal Portbury Dock, north of the Sheephouse Farm rise.

Information from the earlier site investigation can now be discussed in the light of the fieldwork in the Sheepway area.

The boreholes which are encountered in the gravel deposits are Portbury Series Nos. 3, 4, 5, 17, 24, 25, 26 and 29. The logs are given in Appendix I . They confirm the stratigraphy already determined from fieldwork and help to define the areal extent and thickness of the deposits.

Summary of the Sheepway sites :

Fig. 4.38 shows cross-section H running N-S through the Sheepway rise, and indicated the deposits encountered in the A369 ditch, TPs 10-13, and Exposure 1. (Also shown is the borehole information from the Portbury Series Nos. 25 and 26.). This diagram illustrates how the main gravels form a drape over a slight rise in the general level of the Keuper Marl. They are found only on the north end of the rise, between 9.07 and 11.9m O.D., with a possible glacial till deposit in TP11 below this gravel.

From TP11 southwards along the cross-section, the Marl is covered by a thickness of c. 1-2m of muddy sand with varying amounts of gravel included. In view of the evidence from the A369 wedge features and the particle size analysis of this material, it is considered to be a blanket of coversands.

South of TP11 no sandy gravels are encountered but instead a similar thickness of gravelly coversands exists. Around TP10, south of the main Sheepway rise, this has decreased to only 0.1-0.2m of coversands. However, a further area of sandy gravel was found in the A369 ditch between 4.7 and 5.2m O.D. Although very similar lithologically and on particle size analysis to those from the Sheepway Rise, they lie at 1.5 kms apart and 5m lower. Without intervening trenches, whether or not they are related is still uncertain. However, the evidence from the boreholes further to the east may help shed some light on this.

Royal Portbury Dock Site Investigations :

Several sets of boreholes were undertaken prior to the final siting of the Dock. These are shown on Fig. 4.28a. The abbreviations for the borehole numbering are explained as following :

TW1 etc. = Preliminary West Dock Boreholes

S and SG1 etc. = West Dock Boreholes

P1 etc. = probe sites

M301 etc. = M5 motorway boreholes

Boreholes 1 etc. = Portbury Series.

The information derived from these has been treated in several ways :

1) to produce a map of the rock/alluvial boundary (Fig. 4.28b)
2) to produce a map of isopachytes on the gravels (Fig. 4.36)
3) to produce section drawings across the area (Fig. 4.37 and 4.38)
4) to provide descriptions and particle size diagrams of the sediments (Fig. 4.39 and 4.40)

These will now be discussed :

1) The rock/alluvial boundary :

Fig. 4.28b gives the rockhead contours in metres O.D. for the whole Sheepway area, which is underlain by Triassic Keuper Marl. As can be seen, the bedrock has two higher areas, north of Sheepway where it reaches 11m O.D. and around Sheephouse and the area to the south of this, where the top surface rises to nearly 14m O.D. Between these two is a broad, shallow valley running NNW/SSE. The steepest gradient found along the valley sides is to the east of the Sheepway Rise, where the bedrock surface slopes east at 1 in 18 or 3°. This valley continues to the north and out into the Severn Channel.

On the northern side of both the Sheepway and Sheephouse rises, the Marl shelves gently into the Channel, while east of Sheephouse there is a steep slope down towards the River Avon.

2) Isopachytes of the gravel deposits :

These are shown on Fig. 4.36. Obviously the density of borehole data is reflected in the density of information on the gravels, but four main areas can be distinguished :

a) around the Royal Portbury Dock where a roughly circular deposit, reaching a maximum of 5m of gravel, lies generally between -3 to -6m O.D. Here the greatest thickness is to the west and south, while a small valley can be determined between these concentrations. The eastern gravel rests on the Marl at around -4m O.D. but the western group is at -6m O.D., correlating with the edge of the suballuvial buried valley.

b) South of Sheephouse Farm and north of the M5 motorway is a large area of up to 3m thickness of gravel, but with the main deposit lying in the suballuvial valley already noted on the rockhead contour map. The deposit thins to c. 1m thick east of this where the Marl rises to 5m O.D., then increases to over 2m thick as the Marl shelves downwards further east again. The whole gravel deposit lies between 0-5m O.D.

c) On the Sheepway rise where the sands and gravels are up to 2m thick, between 11-9m O.D., and also in the area south of this where 1m+ is found at 4.7m O.D. These have already been discussed above.

d) As the area of Sheephouse Farm is developed for housing and caravans it was not investigated for the Port development. Consequently, although the Geological Maps show the area to be partially overlain by gravel, the thickness has not been determined. The descriptions of the deposits (Hawkins, 1966) suggest it is very similar to that found on the Sheepway rise, with sandy gravels overlain by more muddy gravelly coversands.

3) Section drawings across the area :

As seen in Figs. 4.37 and 4.38, eight cross-sections were compiled from the borehole and fieldwork data. Fig. 4.37 shows the five N-S sections (A, the most westerly, to E on the eastern side) drawn through the gravels in the Royal Portbury Dock area. This depicts the majority of the sandy gravels between -3 to 0m O.D. in the east, whereas westwards their base is below -6m O.D. and they thicken considerably, so that the top surface remains at c. 0m O.D.

In section C, above the sandy gravel, in boreholes TW4, 141 and Probe 7, there is a deposit of up to 4m of red-brown silt, sand and gravel, which is likely to be a thickened lens of coversand material similar to that found around Sheepway. There is also the possibility that it is a till deposit as found in the A369 ditch. The only boreholes immediately south of these sections on the Sheephouse rise are TW6 and BH119. TW6, at 13.5m O.D., found only topsoil over Keuper Marl at 120mm, while BH119 at 16.95m O.D. gave 0.5m topsoil then red-brown, slightly sandy, silty clay with occasional fine gravel for 3m over the Marl at 13.45m O.D. This again represents coversands material or glacial till, here at the highest level seen.

Two of the sections in Fig. 4.38 run E-W : Section F, south of the Sheephouse rise and Section G cutting through the Sheepway rise and continuing across almost to the Avonmouth Bridge. The first shows a relatively thin deposit (1.5m at maximum and generally under 1m), of what is described in the borehole logs as gravel in sandy mud or clayey sand with gravel. This overlies the Marl at heights between -3 to 5m O.D. and it is impossible to say whether it represents remnants of thin sandy gravel deposits, incorporated into the top of the Marl, or gravelly coversand or glacial till. No substantial gravel deposit is found along this section. Thus south of both the Sheephouse and Sheepway gravels there is an area largely clear of gravel before the more southerly deposits begin.

Section G shows a higher level of Marl on the Sheepway Knoll, with a small lens of the sandy gravels found in Borehole 24. Continuing eastwards the section depicts the broad suballuvial valley and along the base of this, between 0 to 5m O.D., is a further deposit of sandy gravel. This material continues across the rest of the section, above the Marl, and thins out as the bedrock slopes down towards the River Avon.

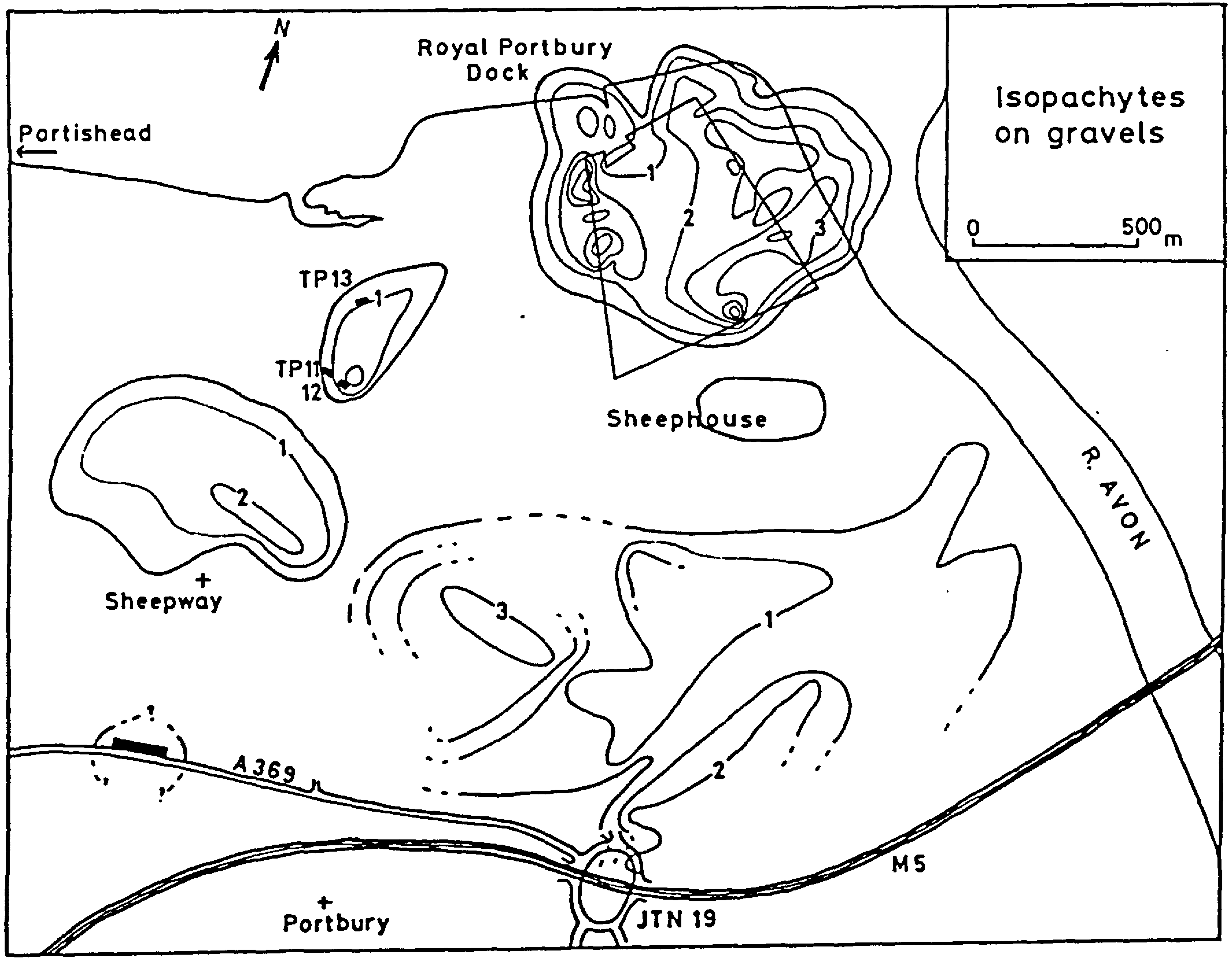


Figure 4.36 :

Isopachytes on gravels, Portbury-Sheepway area

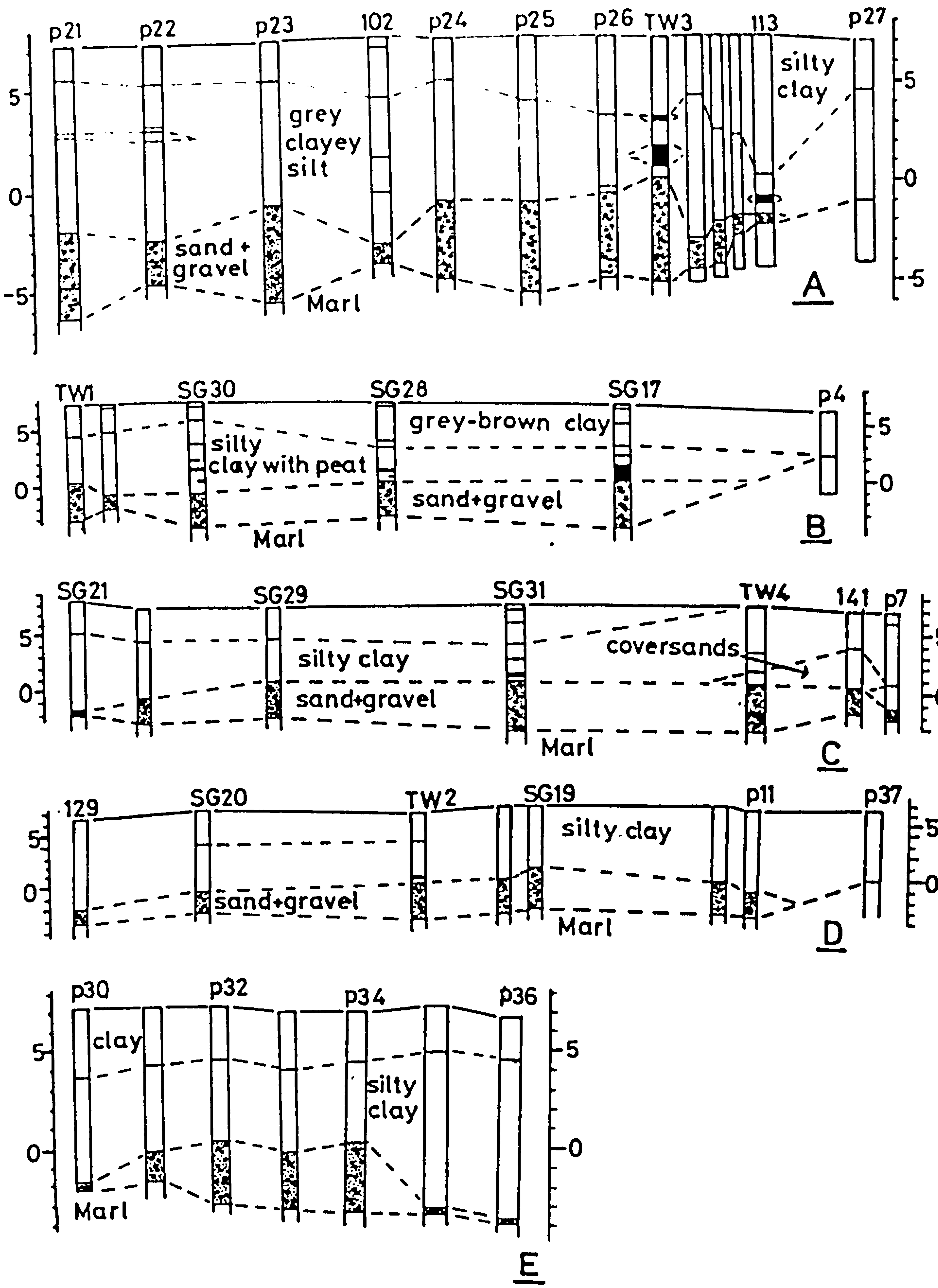


Figure 4.37 : Cross-sections A-E through the Portbury-Sheepway area

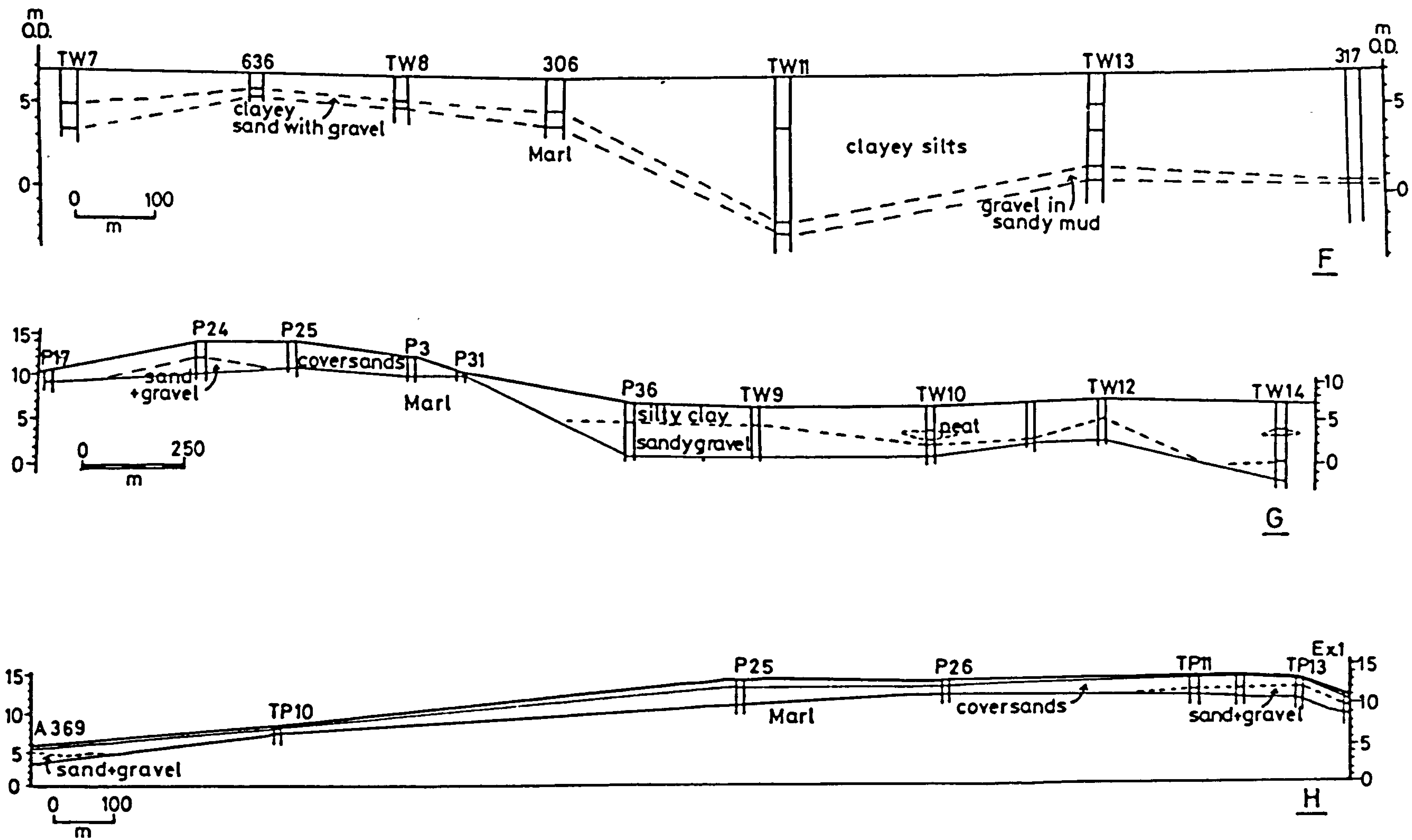


Figure 4.38 :

Cross-sections F-H through the Portbury-Sheepway area

4) Particle size analysis of the sediments :

Fig. 4.39 shows a collection of particle size curves for samples from the sandy gravels in the Royal Portbury Dock area. It has been possible to separate them into three distinct groups of a) gravels, b) sandy gravels, and c) gravelly sands. The gravels are relatively well sorted with less than 8% mud and between 1-22% sand. N.B. No material of coversands or glacial till origin has been included with these sandy gravels.

To attempt to relate these to the samples from Sheepway, the A369 and those from the Access Road area, south of Sheephouse, they have all been plotted on Fig. 4.40. Curves are drawn indicating groups which represent the range of grain sizes found at each site. A clear separation is seen between the Royal Portbury Dock gravels and the sandy gravels. The Sheepway gravels (TPs 11-13) can be seen to fall between these two, so that they show an overall finer mean grain size than those at the Royal Portbury Dock. The A369 group is generally within the range of the Sheepway gravels, further suggesting that they form part of the same deposit. Similarly the only sample from the Access Road area (TW9) lies within the RPD range.

Thus the particle size analyses suggest that there are 2 groups of gravel deposits in the area :

1) at Sheepway and the A369 (between 5 to 11m O.D.)
2) at Royal Portbury Dock (-6 to 0m O.D.) and the Access Road area to the south of Sheephouse (between -2 to 5m O.D.)

This Chapter has described the character of the gravels as seen in temporary and purpose dug holes within the research area. In order to assess more clearly the nature and relationships of all the deposits studied, it is necessary to compare their sedimentary statistics, form, and lithologies.

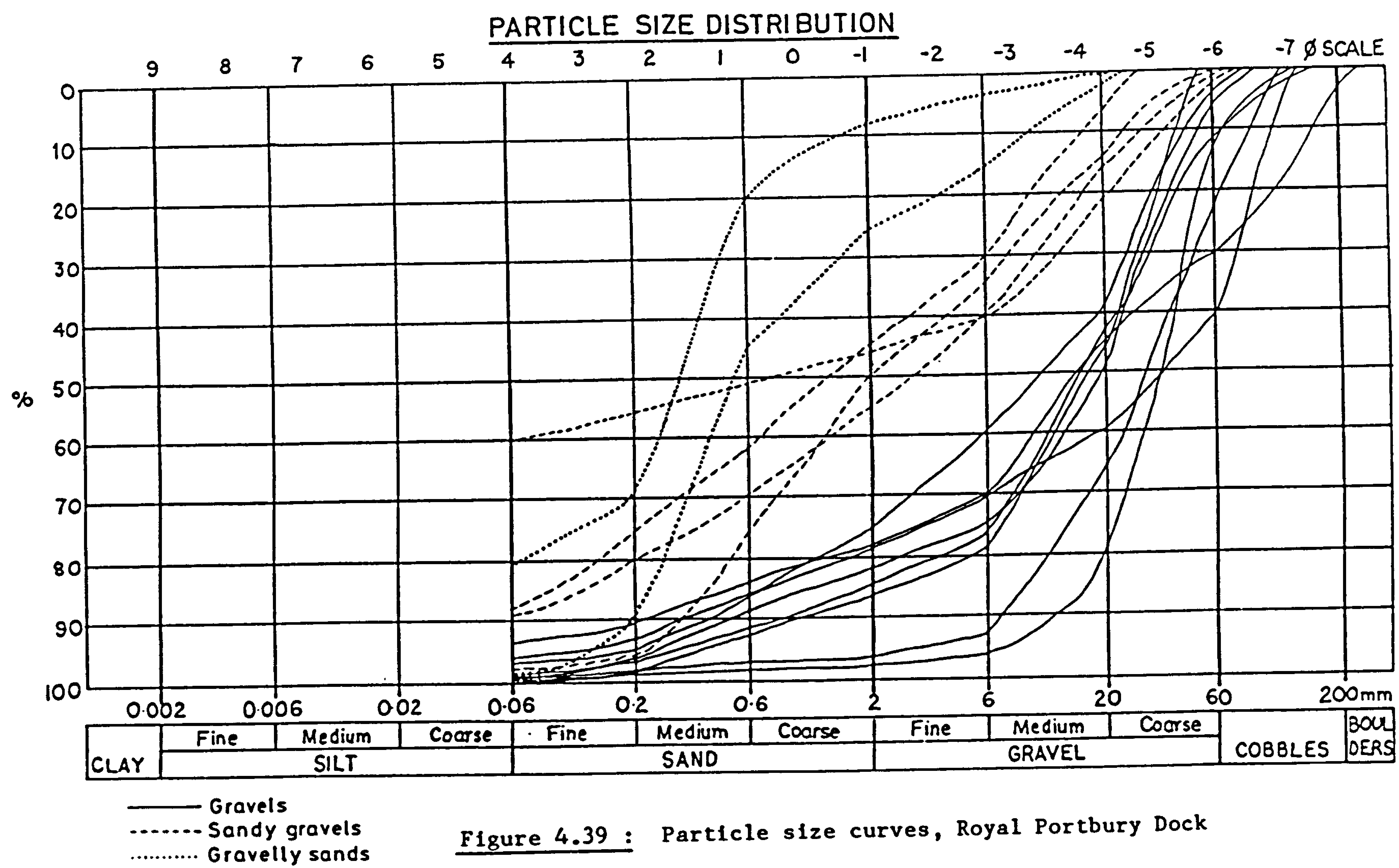


Figure 4.39 : Particle size curves, Royal Portbury Dock

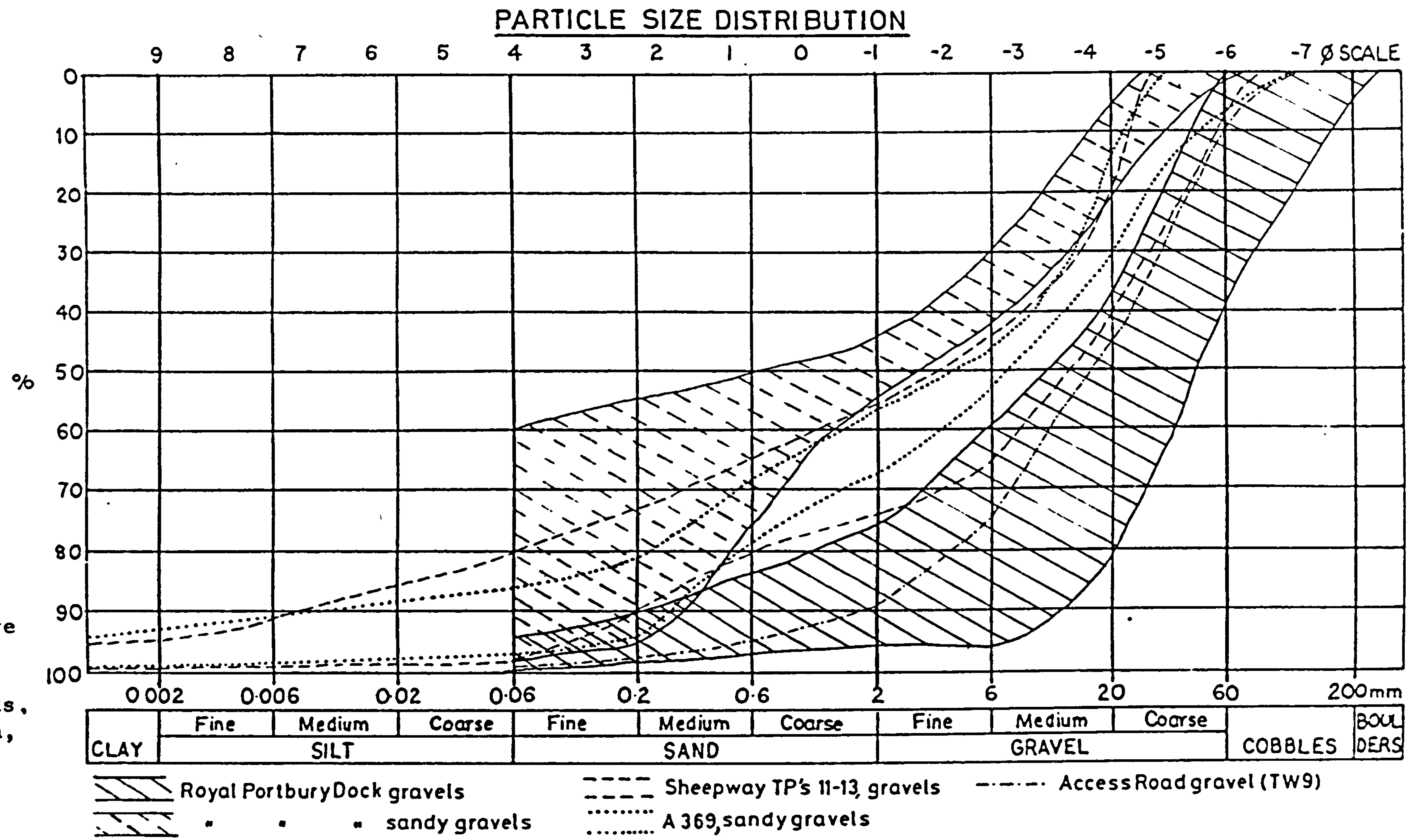


Figure 4.40 :

Particle size curve ranges : Royal Portbury Dock, Sheepway Trial Pits, A369 ditch section, and Access Road site

CHAPTER 5

SEDIMENTARY STATISTICS :

Following the fieldwork, some of the samples collected were tested for :

1) Particle size analysis and computing of sedimentary statistics from this data.
2) Analysis of the lithologies.
3) Measurement of the size and shape parameters of the gravels.

These tests allowed a more detailed description of the samples and a comparison of their various sedimentary characters.

SECTION 1 :

PARTICLE SIZE ANALYSIS AND SEDIMENTARY STATISTICS :

The methods employed to obtain particle size distributions of the samples have already been described in Chapter 2. From this data the following sedimentary statistics were derived :

A) Cumulative curves of grain sizes.
B) Folk Measures of average size and sorting.
C) Folk Measures of skewness and kurtosis.

An example of the type of computer print out produced for each sample is included in Appendix IV. From these print outs the various parameters were extracted for comparison. It was decided to use the Folk Sedimentary Measures to prepare the diagrams and graphs since these are the most appropriate for the type of samples collected in the present study (Folk and Ward, 1957; Folk, 1968; Buller and McManus, 1972). The Measures are computed by reading the grain size diameters represented by the various percentages from the cumulative curves. Often a Measure will only use the data between the 5th to 95th percentiles, hence "odd" end values (e.g. from insufficient sampling) are not included in the calculations. The alternative to this method is called the Method of Moments and relies on using all values from a sample. As a result of this, the Method may not give a valid parameter for samples where all the ϕ classes are not represented accurately. It is of great value when analysing, for example moderately sorted sands, but loses its effectiveness as sorting decreases as found, for example, in the Bristol Avon gravels. The Folk Measures, whilst using only selected percentages to calculate parameters, is of more use with this size range of materials. Another advantage is their widespread usage and hence the ability to compare results.

Table 5.1 gives the formulae used in calculating the Folk Measures :

Measure	Symbol	Calculation
Mean	MZ	16% + 50% + 84% / 3
Sorting	σi	$\frac{84\% - 16\%}{4} + \frac{95\% - 5\%}{6.6}$
Kurtosis	Kg	$\frac{95\% - 5\%}{2.44\ (75\% - 25\%)}$
Skewness	SK_1	$\frac{[(84\% + 16\%) - 2(50\%)]}{2(84\% - 16\%)} + \frac{[(95\% + 5\%) - 2(50\%)]}{2(95\% - 5\%)}$

A) <u>CUMULATIVE CURVES OF GRAIN SIZES</u> :

The curves were drawn with an arithmetic ordinate axis as the results are easier to "visualise" than those of cumulative curves with a probability ordinate, which gives a perfectly straight line for each sample.

Fig. 5.1 shows the range of results obtained from the gravel dominated sediments. Fig. 5.1A includes those samples taken between Bathampton and Stidham Farm. Where a number of samples were analysed, the lines drawn show the range of values for each site. Thus the samples from Bathampton, the A36, Newton St. Loe and Keynsham are seen to fall within the range of the Stidham group. All these deposits have between 50-80% gravel and less than 5% clay.

Figure 5.1B shows the range of results from Sheepway, the A369 site, and TP30 at Wraxall. The Sheepway examples contained a much greater % of mud (up to 45%) and between 25-70% gravel. The A369 gravels however are very similar to those from the Stidham range. Figure 5.1C shows the ranges at

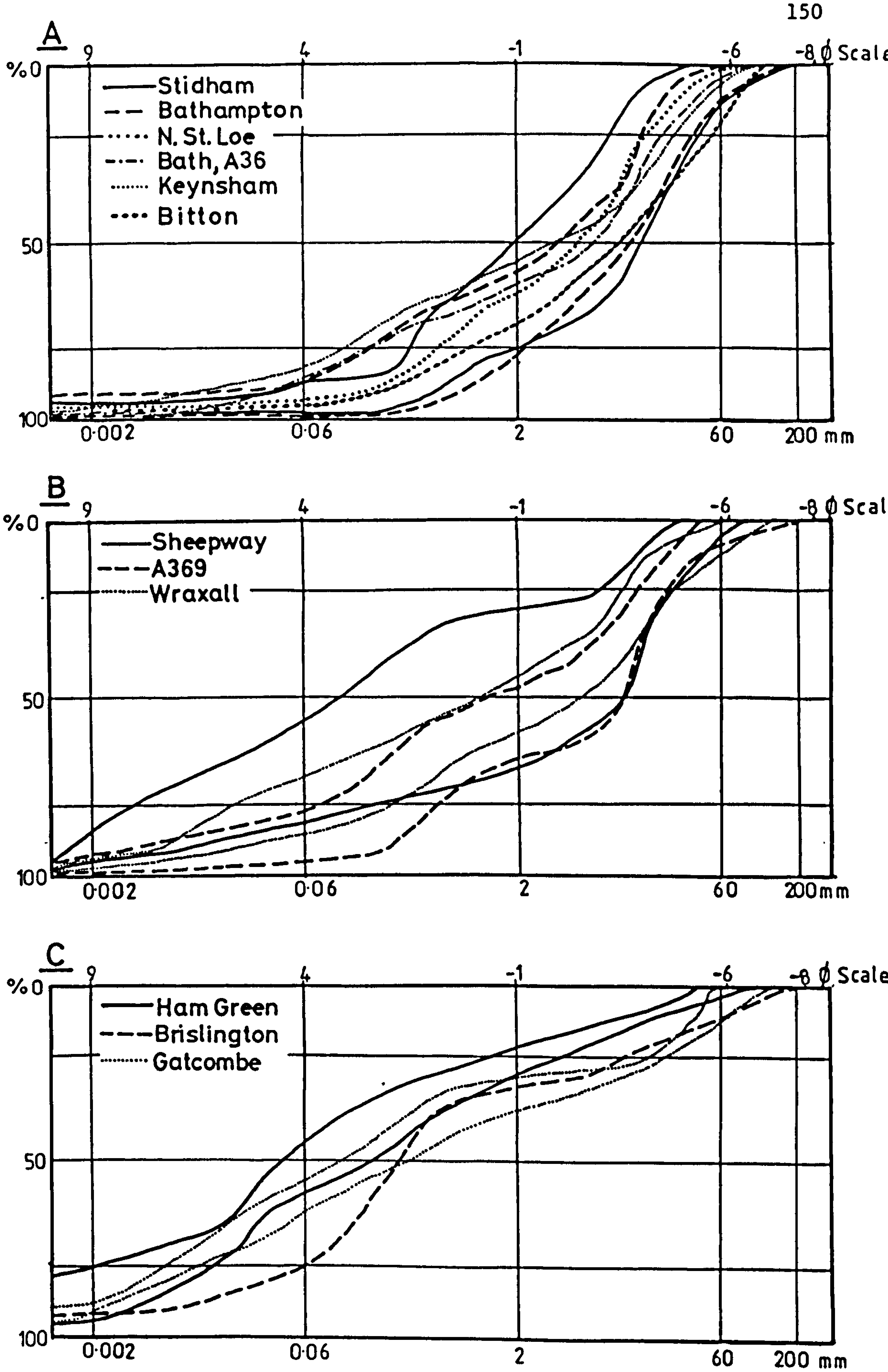


Figure 5.1 : Cumulative curves of particle size distributions

Ham Green, Gatcombe and Brislington. The Ham Green gravels included the largest amounts of mud (with up to 35% silt and 20% clay). As such they were the worst sorted of all the deposits analysed.

Another method of representing the particle size information is by plotting it in a triangular form, with the samples positioned with reference to the three end members. To show the variability of samples two diagrams were prepared : Fig. 5.2 has end members representing 100% gravel, sand and mud, while in Fig. 5.3 they represent 100% sand, silt and clay. When plotted, most of the samples are separated into groups of similar composition. In conjunction with the field descriptions of these samples, the groupings can be used to make general suggestions about possible environments of deposition. The depositional groups, as assessed in the field, have been added to the sedimentary triangles, and support the broad indications of sedimentary types.

Fig. 5.2 shows the samples from the Bristol area with reference to their ratios of gravel : sand : mud. The most obvious feature is the relatively better sorting of the Stidham deposits, which all plot near the gravel and sand margin. Those samples from Stidham Layer 4 (the upper, grey, and finer gravels) plot close to this margin, while those of Layer 5 (the lower, orange and coarser gravels) have slightly more sand and mud. This differentiation is discussed further with reference to Fig. 5.4. The Bathampton and Bitton samples group with Layer 5.

Below the Stidham and Bathampton samples on Fig. 5.2 is a group which includes the main gravels in TP30 at Wraxall and the Sheepway pits. The Keynsham and Bath (A36) samples are also found in this group, perhaps because of the inclusion by leaching and downwashing of alluvial muds into these gravels, thus giving a less well sorted gravel. The group has been termed fluvial/fluvioglacial gravels.

In the centre of the triangle are two groups of samples, which have roughly equal ratios of gravel : sand : mud. In view of their field characteristics, these are separated into :

a) fluvioglacial (+ possibly redeposited till), which includes Wraxall TP30/7, A369 ditch sample 7 and Sheepway TP13/5.

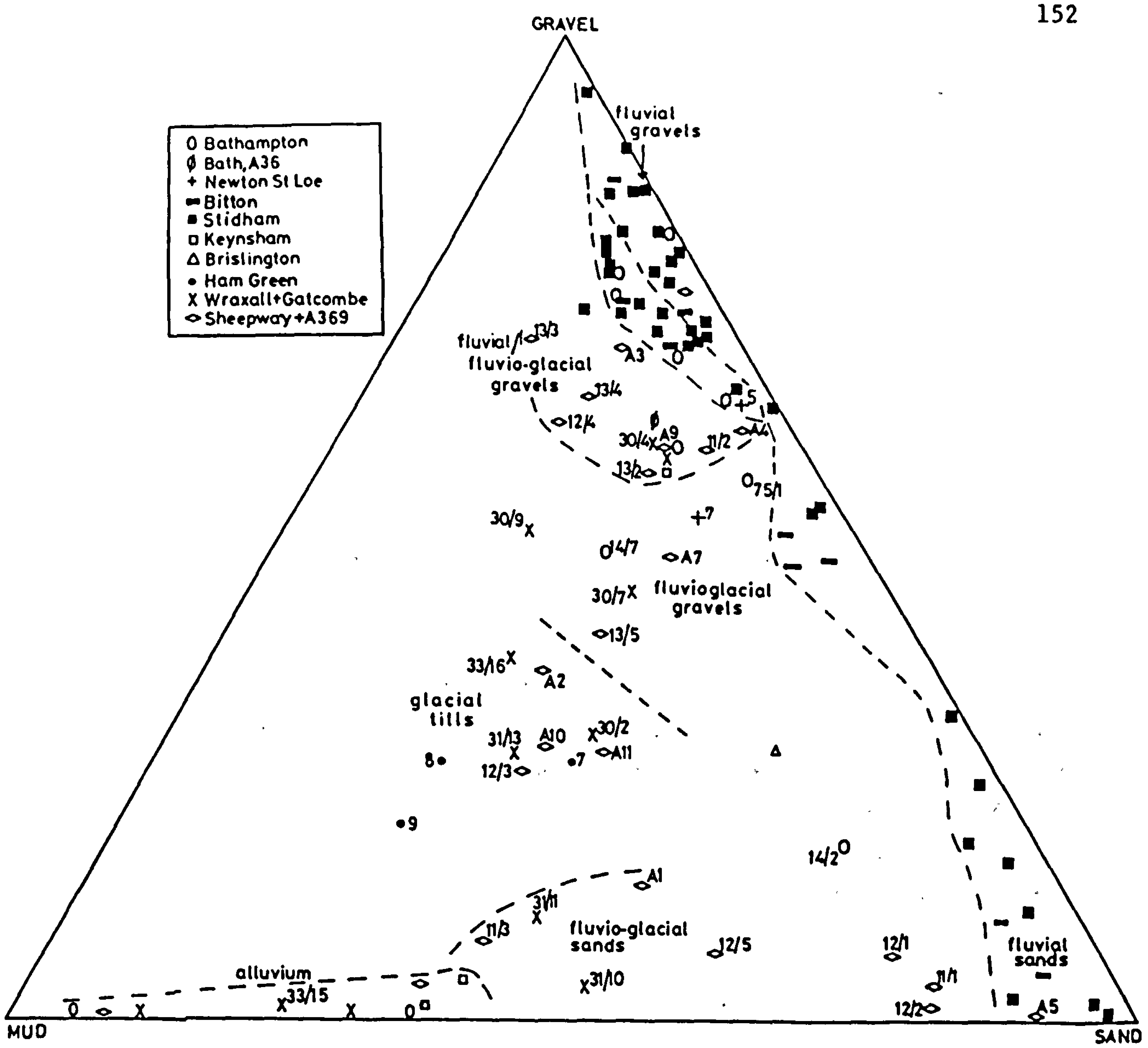


Figure 5.2 : Ratios of gravel : sand : mud

b) glacial tills, from Ham Green samples 7, 8 and 9, Gatcombe TP33/16, 31/13, Wraxall 30/9, Sheepway TP12/3, and A369/2, 10, and 11.

It should be noted here that the till samples separate well into their respective sites :

a) the Wraxall till (TP30/9) has a greater amount of gravel (50%) than the others;
b) the Ham Green till (HG8,9) is mud dominated (> 50%);
c) the Gatcombe till (TP33/16 and 31/13) have roughly equal amounts of mud and gravel, and slightly less sand;
d) the A369 samples (A369/2,10,11) have roughly equal amounts of mud and sand and slightly less gravel.

Sample TP2/4 from Brislington plots towards the sand end member, with roughly equal amounts of gravel and mud, as does Bathampton TP14/2, the gravelly muddy sand above the main terrace material, which was considered to be a hillwash deposit. This reflects the rapid deposition of the whole range of particle sizes by solifluction processes. However sample TP14/7 from Bathampton, the angular hillwash, groups with the samples of fluvio-glacial type. Sample TP75/1, from the same deposit, has far less mud and plots as a sandy gravel.

Finally, along the base of the triangle in Fig. 5.2, are those samples with very little gravel. The Stidham sands are once again relatively well sorted and near to their predominant end member. A further group of less well sorted sands, with between 15-60% mud and less than 15% gravel, includes the Sheepway, Gatcombe and Wraxall samples. On field evidence these are suggested to be fluvioglacial sands. The alluvial silts and clays found at the various sites plot towards the mud end member, all with less than 5% gravel.

Fig. 5.3 is a further triangle with end members of sand : silt : clay. On this diagram the matrices of the gravelly deposits have been plotted taking their total amount of sand, silt and clay as 100%, i.e. ignoring their gravel content. This illustrates the amount of sorting within the matrix of a deposit. True glacial deposits, for example, are often found to have an equilibrium of sand, silt and clay (Leeder, 1982; Kukal, 1971). Reworking by running water decreases the amount of fines deposited, so that the clay fraction in fluvioglacial deposits is reduced.

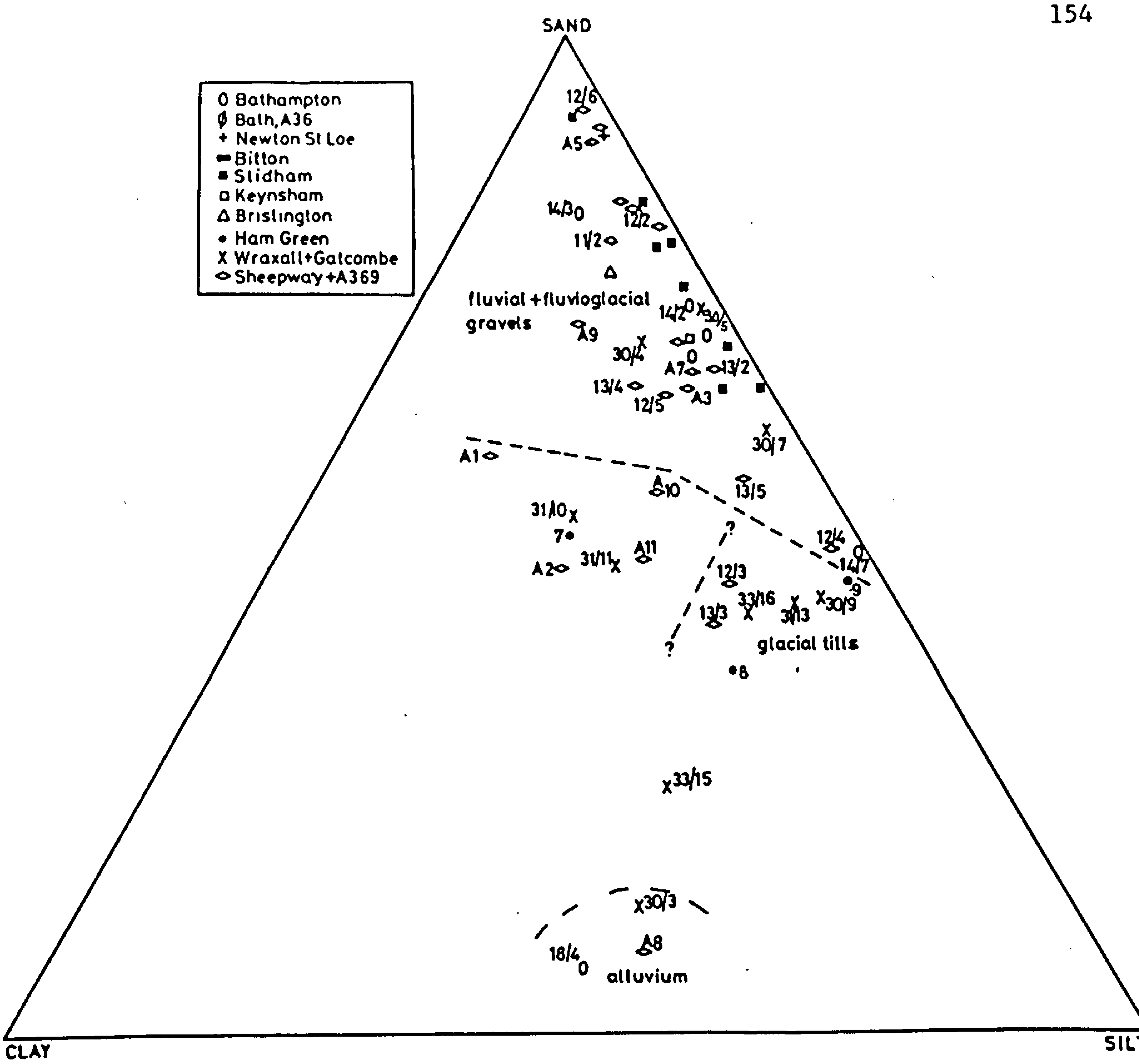


Figure 5.3 : Ratios of sand : silt : clay

The Bristol/Avon samples fall into the same groups as on the former gravel : sand : mud triangle, with the main group of gravels concentrated towards the sand end member (N.B. those samples on which no pipette analysis was performed could not be plotted, since the amount of clay contained is not known). The group includes those gravels previously described as fluvial and fluvioglacial. Those samples thought to be of glacial till show roughly equal amounts of sand and silt, though with less clay than might be expected. In fact those that may include some coversands material (A369/1,2,10,11) are closest to an equilibrium of their three components. The alluvial deposits are found with equal amounts of clay and silt, and very little sand. The two triangular diagrams therefore are of great use in separating the samples into groups of similar composition. They take no account however of the actual grain sizes or sorting of the samples.

B) FOLK MEASURES OF AVERAGE SIZE AND SORTING :

A common method used to illustrate this is to plot the samples on axes of Folk Sorting (σ_1) against Folk Mean grain size (MZ). Primarily this will indicate the variability of sorting with size (and thus which modes of the sediments are the best/worst sorted). Secondly the diagram should distinguish gravels from the various sites and regimes.

Fig. 5.4 shows the Bristol Avon samples plotted in this way. Again the Stidham group of gravels is distinguished by their relative better sorting and coarser mean grain size. It is notable that the coarsest sediments, with MZ between -2 to -3ϕ (medium gravel) have the greatest sorting range, from 1.2ϕ to 3.5ϕ. As the Mean size decreases to about -1ϕ (coarse sand to fine gravel), then the range of sorting values also decreases. This suggests that these samples are of a "purer" type, while the coarser gravels contain proportions of various grades. The sand samples (from -1ϕ to 1ϕ Mean size) are relatively better sorted than the gravels and have a smaller standard deviation.

Fig. 5.4B shows an enlargement of the same data from the Stidham samples. The gravels are plotted using the sedimentary layers given in Chapter 4 which are repeated here for convenience :

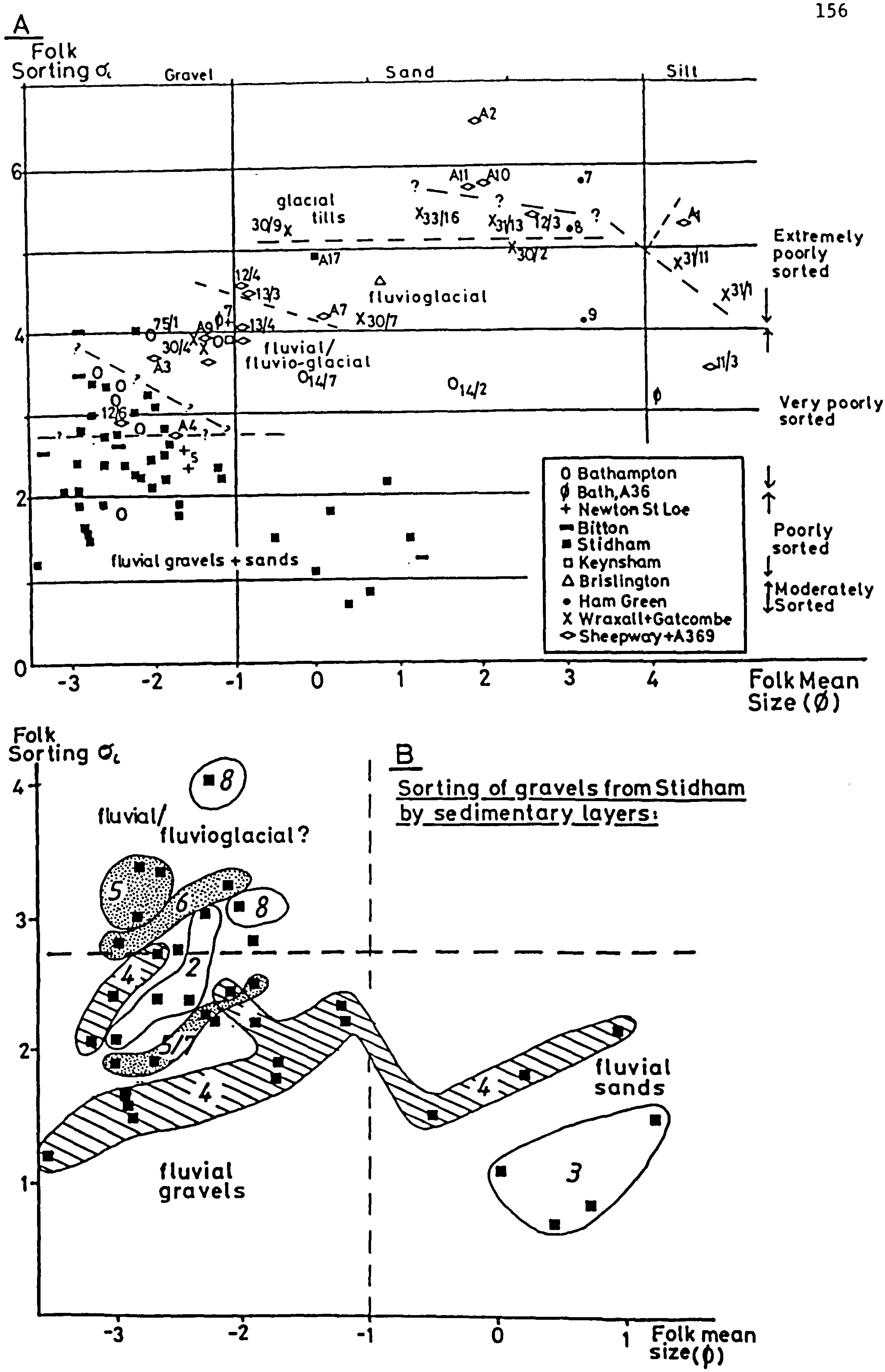


Figure 5.4 : A. Folk Sorting index versus Folk Mean Size
B. Enlargement of Stidham sorting versus mean size data

Layer 2 = uppermost sandy gravel

Layer 3 = coarse sand lens

Layer 4 = upper grey finer gravels

Layers 5,6,7, 5/7 = lower orange coarser gravels

Layer 8 = grey, muddy sandy coarse gravel.

Layers 3 and 4 are the best sorted, with a maximum σ_i of 2.75ø. The differentiation between the Layer 3 and Layer 4 sand presumably reflects the purer coarse sand of the former and the slight admixture of gravel in the latter.

Layers 5 and 6 have an σ_i of greater than 2.75ø, whereas that of Layer 5/7 is between 1.8 to 2.5ø. This reflects the slightly muddier natures of Layers 5 and 6. The two samples from Layer 8 are very poorly sorted as expected from the field evidence. Layer 2 plots between Layers 4 and 5.

The field distinction between the lower coarse gravels and the upper finer and better sorted deposits is therefore confirmed in this graph comparing size with sorting, and in the triangular diagram of gravel : sand : mud ratios. On this evidence it is suggested that Layers 5-8 at Stidham represent material deposited by more variable and fast, turbulent flows. Layers 3 and 4 seem more the product of lesser but more regular flows transporting finer, better sorted material which was then deposited as a typical fluvial terrace. Layer 5/7 is an intermediate deposit between these two types.

It is known that most fluvial sediments show a sinusoidal relation between sorting and size. Griffiths (1967) states that the best sorted sediments have a mean size of 2-3ø (fine sand) and -3 to -5ø (coarse gravels). The worst sorting is shown by those of 0 to -1ø (coarse sand) and 6 to 8ø (fine silts). The Stidham samples are interesting in that they appear to form one cycle of a sine curve. Samples from Layer 4 especially follow this relation, with the best sorting at -3.5ø (coarse gravel) and 0 to 1ø (coarse sand). The worst is at around -2.5ø (fine gravel).

Returning to Fig. 5.4A, the Newton St. Loe samples are seen to fall within the range of those from Stidham Layer 4, whereas only sample TP15/5 from Bathampton is as well sorted. The Bathampton terrace gravels (samples

15/2,4 and 14/3,8) are more closely related to Stidham Layers 5-7, as are most of the Bitton samples. One sample of the A369 ditch site (A369/4) lies within the range of these samples.

The Bathampton, Bitton and Stidham samples therefore form a distinct grouping with all other samples from the Bristol Avon area being more poorly sorted (i.e. with a sorting coefficient of greater than 3.5ϕ).

The next cluster of samples plot between 3.6 to 4.6ϕ, and with mean sizes of from -3 to -1ϕ. These include those from Bitton (Boyd stream section), Bath A36/1, Keynsham TP9/8, Wraxall TP30/4 and 5, A369/3 and 9, and from Sheepway TP11/2, TP12/4, and TP13/2,3,4. These are all examples of sandy, muddy, fine to medium gravels. Their very poor to extremely poor sorting suggests a fluvioglacial origin. They may have originated when melts occurred in a glacial area, causing reworking of superficial debris (both of morainic and weathering origins). Transportation by running water causes the removal of much of the silt and clay, but the fast turbulent discharges result in a rapidly deposited and very poorly sorted material. Flows of constant strength, whether of high or low energy, result in better sorting of materials than those typical of fluctuating regimes.

Due to the lack of further evidence of glacial or periglacial deposits at Bitton, Bath and Keynsham, this group of gravels have been classed as fluvial/fluvioglacial. Indeed it has already been noted that the amount of mud (and therefore the higher sorting coefficient) in the Bath, A36 and Keynsham samples may be due to post-depositional inclusion of alluvial material. However those samples from Wraxall, the A369, and Sheepway are found in close association with glacial deposits and periglacial phenomena. Considering all the evidence, it is extremely likely that they are the result of deposition by fluvioglacial streams.

On Fig. 5.4A the finer grades of material (-1 to 1ϕ Mean size) are even less well sorted than the larger gravels, with sorting values of greater than 4ϕ; e.g. A369/7, Sheepway TP12/4 and 13/ and Wraxall TP30/7. In contrast to the typical fluvial channel sediments from Stidham which improve in sorting as their mean size decreases, these fluvioglacial examples show a deterioration in sorting as they grade towards the smaller grain sizes. This would be explained by the material being redeposited by rapidly fluctuating stream discharges, close to the site of original deposition. As a result there would be a greater retention of fines and therefore poorer sorting, than that of the coarser fluvial deposits. The latter were carried by stronger and slightly more constant currents and are therefore better graded.

The hillwash materials recorded from Bathampton range from a sorting value of 3.3Ø for the soliflucted muddy sand (TP14/2) to 3.5Ø and 4Ø for the angular gravel hillwash (TP14/7 and TP75/1). The deposits are therefore relatively better sorted than the fluvioglacial sediments, and show a slight increase in grading as the grain size increases.

Those samples with a sorting poorer than 5Ø σ_i are unlikely to have been deposited by running water. Their wide range of constituents results in a mean grain size within the sand range, even though the samples include pebbles of up to -8Ø size and contain up to 40% mud. They are interpreted as of glacial till because of this extremely poor sorting and their near equilibrium of gravel, sand and mud. The samples concerned are Wraxall TP30/9, Gatcombe TP31/13, TP33/16, Sheepway TP12/3, and Ham Green/8.

A further group of samples on Fig. 5.4A are even less sorted than the tills. These have a mean grain size of between 2-3Ø and a Folk sorting of 5.75-6.5Ø. The actual samples are A369/2,10,11 and Ham Green/7, and consist of red brown muddy sand with gravel.

All these samples produced grain size histograms showing three peak modes : at 8Ø, 2-3Ø, and at -4 to -5Ø (fine silt, fine to medium sand, and coarse gravel respectively). This trimodal distribution results in the extremely poor sorting values. The predominant mode varies between the samples e.g. in A369/2 it is coarse gravel, in A369/10 it is fine silt, and in A369/11 it is medium sand. They also show correspondingly low amounts of coarse silt and coarse sand.

The previous discussion as to whether these sediments were of a) glacial till or b) coversands incorporated into gravels by both cryoturbation and leaching can now be extended. If the second hypothesis were the case, the sediments would be expected to have a high fine sand fraction (2-4Ø). The coversands from Kenn, analysed by Gilbertson (1974) contained 60% of this size grade. The maximum found in the A369 samples was 32% of 2-4∅ size. The problem arises in accounting for the incorporation of up to 35% gravel size material and up to 22% of fine to medium silt size.

The trimodal distribution is characteristic of other glaciogenic deposits found in the present study (from Ham Green and Gatcombe) and is typical of the mixture of grades generally found in glacial tills (Folk, 1968; Leeder, 1982). Onbalance the evidence supports deposition of the material during a glacial episode, with possible later accumulations of coversands over this. Some incorporation and mixing of the two deposits may have occurred during the subsequent cryoturbation of the deposits.

Returning to Fig. 5.4A, those deposits with a mean grain size within the silt range of 4.5∅ include a further sample from the A369 ditch (here with only 12% gravel and thus a sorting value of 5.25∅), and samples 31/10,11 from Gatcombe, which are the muddy sands overlying the glacial till. These are interpreted as coversands/"coversilts" because of their stratigraphic position in the field, and their sorting values of 4-5-5.25∅. However some redeposition by water may have occurred.

Below these on Fig. 5.4A are samples from Newton St. Loe TP8/2, Sheepway TP11/3, and Bath A36/1, with sorting of between 3.2-4.1∅. From field evidence they would appear to be alluvial silts and sands and indeed their sorting values suggest deposition by running water.

C) FOLK MEASURES OF SKEWNESS AND KURTOSIS :

Skewness

This is a measure of the amount of asymmetry of the cumulative curve of particle size, and whether the asymmetry is positive (an excess of fines) or negative (an excess of coarse material). Skewness limits range from -1.0 to +1.0 and the verbal descriptions commonly used are as follows (Folk, 1968) :

-1.0 to -0.3	strongly coarse skewed
-0.3 to -0.1	coarse skewed
-0.1 to +0.1	near symmetrically skewed

+0.1 to +0.3	fine skewed
+0.3 to +1.0	strongly fine skewed

The measure emphasises the modality of a sediment e.g. a unimodal material will have extreme skewness, with the sign dependent on the predominant mode.

Kurtosis :

This is a measure of the peakedness of the cumulative curve of particle size. It compares the sorting in the central part of the curve with sorting in the tails of the distribution. Thus a better sorted central portion gives a pronounced peak and is termed leptokurtic. If the tails are better sorted then the curve is flattened and called platykurtic. A bimodal sediment will have a platykurtic curve whereas a sediment of predominantly one mode will be leptokurtic. The limits of kurtosis are from 0.41 to infinity; and the verbal limits used are (Folk, 1968) :

less than 0.67	very platykurtic
0.67 to 0.9	platykurtic
0.9 to 1.11	mesokurtic
1.11 to 1.5	leptokurtic
1.5 to 3.0	very leptokurtic
more than 3.0	extremely leptokurtic

The distribution of kurtosis values in sediments is skewed and therefore a transformation of the values is necessary to normalise this. Values are transformed by the formula $\frac{KG}{(KG+1)}$ and they have the symbol KG_1.

Skewness versus sorting :

Fig. 5.5A is a graph of Folk Skewness against Folk sorting, two geometrically independent measures. The same groups of deposits as separated on Figs. 5.3 and 5.4 have been differentiated on the graph.

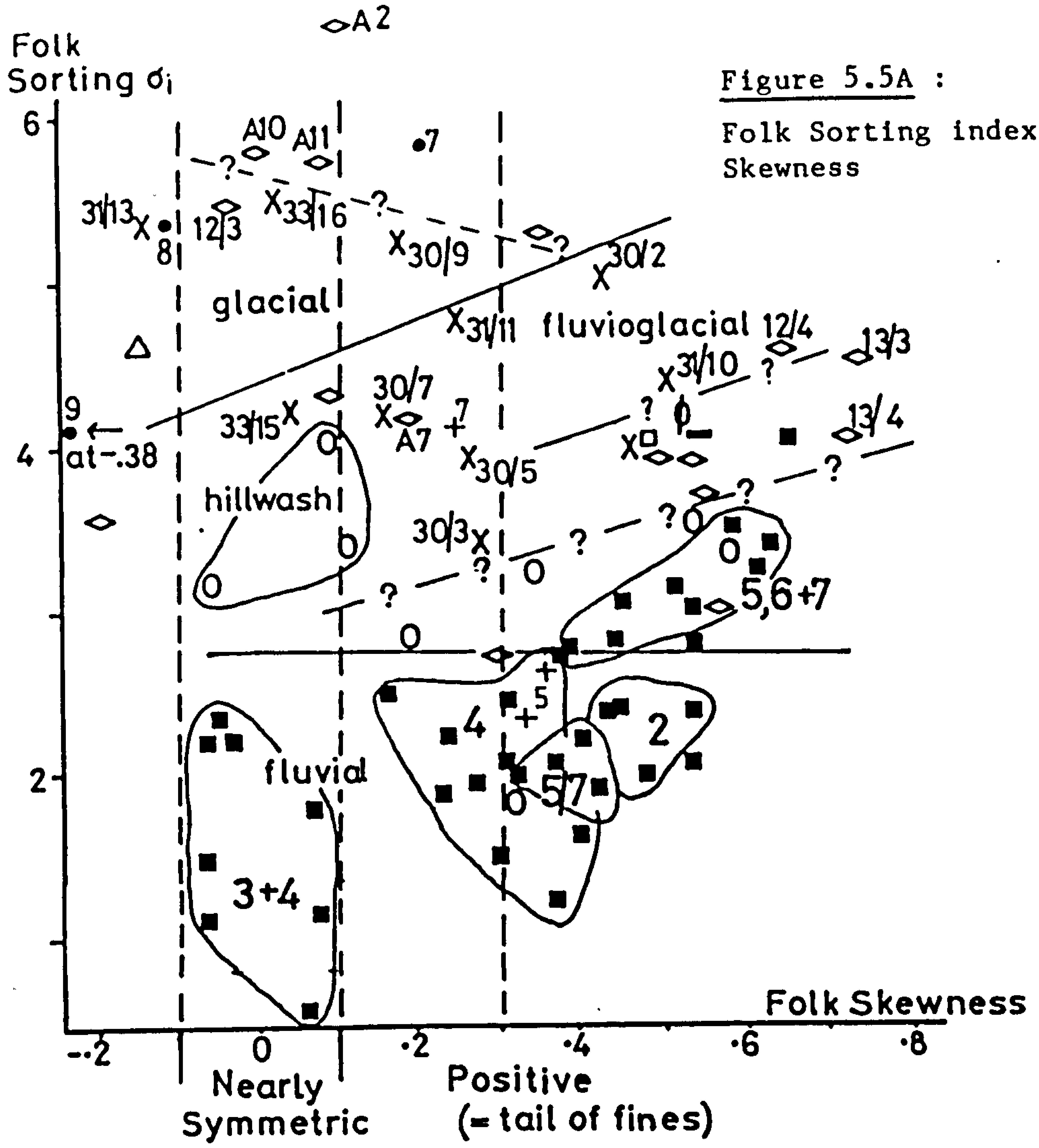


Figure 5.5A : Folk Sorting index versus Folk Skewness

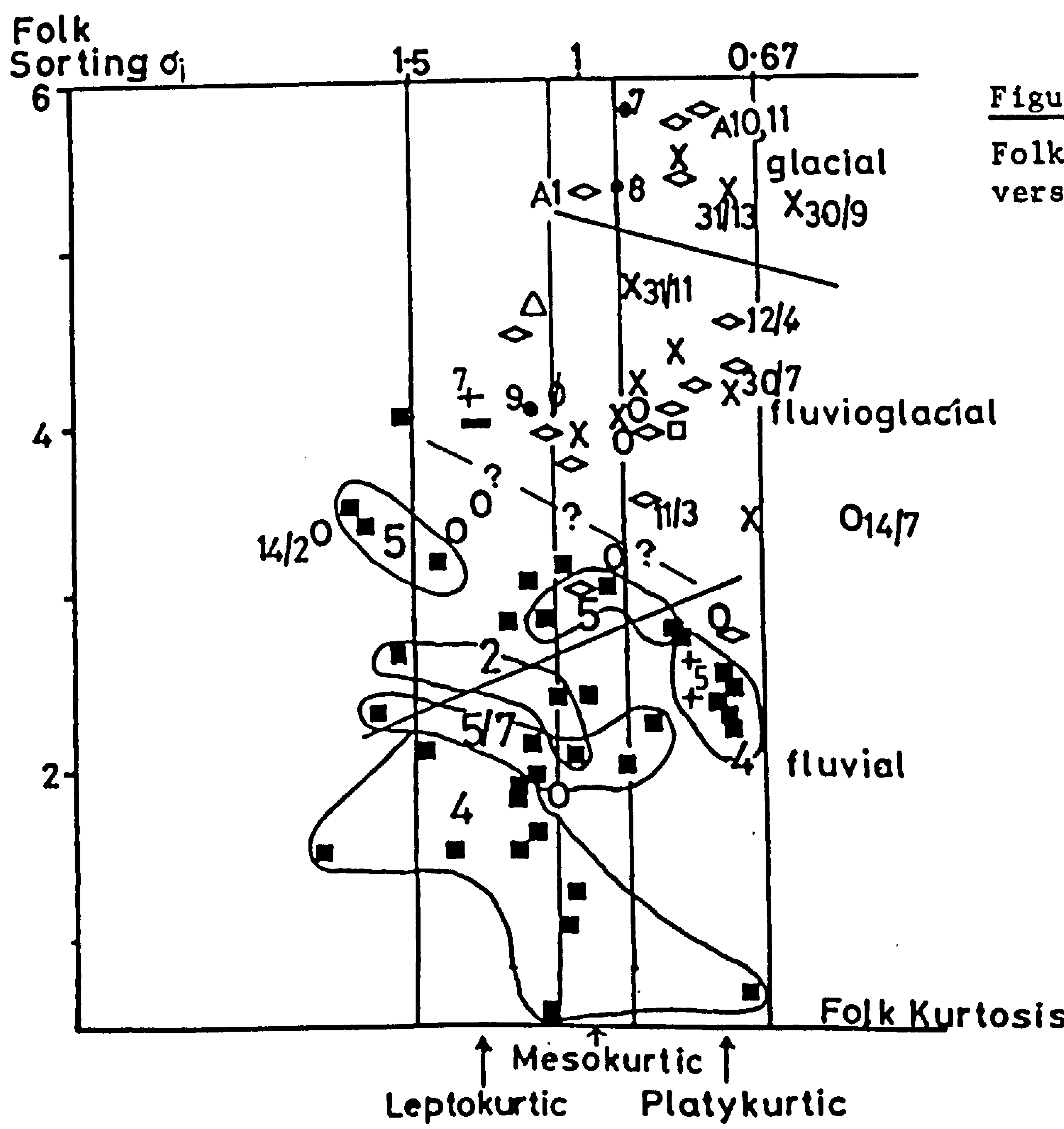


Figure 5.5B : Folk Sorting index versus Folk Kurtosis

The majority of the samples are positively skewed, having a distribution curve with a tail of fines. It is important to note that faulty sampling of coarse gravels could produce such a result i.e. an insufficiently large sample would favour the amount of fines instead of coarse material. However the most positively skewed samples are from Sheepway 12/4, 13/3, and 13/4, which have mean grain sizes of coarse sand. Even if the gravel component had been insufficiently sampled, the mean size would still be expected to lie within the gravel range. The coarsest samples (e.g. Stidham A/6,9,11,21,23,30) have skewness values of between +0.4 to +0.55, compared with the Sheepway values of +0.6 to 0.75. It is therefore likely that the field methods used were adequate in obtaining samples that were representative of all grades of material.

The fluvial gravels from Stidham again separate into their respective layers, with the upper grey finer gravels (Layer 4) ranging from +0.2 to +0.4. Layer 5/7 ranges from +0.3 to 0.425, while Layers 5, 6 and 7 lie between +0.4 and 0.625. This confirms that Layer 5/7 is intermediate between the lower coarse orange gravels of Layers 5, 6, and 7 and the upper grey finer material of Layer 4.

Layer 2, the uppermost gravel, has skewness values similar to Layer 5, though the former is better sorted. The sand samples of Layers 3 and 4 have a near symmetrical skewness, suggesting that they are a unimodal sediment, perhaps from a single source, even though they have a wide range of sorting by size.

The Bathampton fluvial gravels range from +0.2 to 0.6, within the range of the Stidham examples but less well sorted. The two angular hillwash samples have values of +0.1, while the soliflucted muddy sand plots at -0.1. Both are therefore near symmetrical, due perhaps to their being derived almost exclusively from the local weathered limestone bedrock, and not moved far from their source.

The samples from Newton St. Loe group with Stidham Layer 4. However the A36, Keynsham and Bitton Stream section gravels plot near to each other around +0.5 SK. They are therefore closer in skewness to Layers 5, 6, and 7 of Stidham. On sorting they group with those gravels from Sheepway, Wraxall and A369. Their skewness values however range from +0.25 to 0.8, so that these statistics show only that they have a wide range of positive skewness. It is notable that Sample A369/7, the grey-green very muddy gravel found along the base of the ditch, and which was considered a glacial till on field evidence, plots with the fluvioglacial gravels, in terms of both size and sorting. Its gravel constituents and general nature suggest at least a close derivation from a till deposit, and it will now be considered as of glacial origin, partially redeposited by fluvioglacial action.

The group of possible glacial deposits, including Wraxall TP30/9, Gatcombe TP31/13 and TP33/16, and Ham Green/8 have near symmetrical skewness, reflecting the balance of constituents. This is the typical skewness value for glacial sediments. Sample Ham Green/9 is the one deposit that gave a strongly negative skewness, i.e. a tail of coarse material, which again is common amongst glacial muds containing some pebbles.

The final group consists of the A369 till and Sample 7 from Ham Green, showing the worst sorting of all the samples. These again have a near symmetrical skewness due to the balance between the predominant grades of material, further supporting the theory of a glacial origin.

Kurtosis versus sorting :

Fig. 5.5B shows the kurtosis values of the samples, from which some general points emerge. The Layer 4 deposits from Stidham range from the leptokurtic sands, with a single predominant mode, to the platykurtic gravels, with two subequal modes of sand and gravel. In contrast Layers 5, 6, and 7 range between mesokurtic and very leptokurtic, showing a greater predominance of medium to coarse gravel and less sand size material, but with a larger amount of fines than Layer 4. The Bathampton gravels again plot with a similar kurtosis to that of Stidham Layers 5, 6 and 7.

The fluvial/fluvioglacial group divides into those leptokurtic samples e.g. A36/2, Bitton and Newton St. Loe gravels, and secondly, the platykurtic ones from Sheepway 11/3, 12/4 and 13/2,5, Wraxall TP30/7, Gatcombe TP31/10,11 and Keynsham TP9/8. The main gravels from Wraxall TP30/4,5, and A369/3,9 (most likely to be fluvioglacial, on the basis of field evidence) lie between these two, within the mesokurtic range. This is due to a lesser amount of fines to balance the amount of gravel constituents, which again suggests that the main gravels were deposited by slightly stronger and more constant flows than the lower less sorted deposits (e.g. A369/7 and Wraxall TP30/7).

The glacial samples are typically platykurtic (Gatcombe 33/16, 31/13, and Ham Green/8), while Wraxall TP30/9 has a very platykurtic value, again illustrating the balance of constituents. The A369 samples group closely with the glacial materials.

Therefore certain combinations of skewness and kurtosis values can be described for the different groups of samples. These can perhaps be related to sedimentary environments, or, more simply, used to separate the various deposits found. These broad groups are as follows :

GROUP	Skewness	Kurtosis	Sorting
Fluvial sands (Stidham & Bitton)	Near symmetric	Leptokurtic	Moderate - poor sorting
Fluvial gravels I (Stidham Layer 4)	Fine SK	Platykurtic	Poorly sorted
Fluvial gravels II (Stidham Layers 5 to 7, Bathampton)	Strong fine SK	Mesokurtic-Leptokurtic	Very poorly sorted
Fluvial gravels III (A36/2, Bath; Bitton; Keynsham)	Strong fine SK	Leptokurtic-Platykurtic	Very poorly sorted - extremely poorly sorted
Fluvioglacial gravels I (Wraxall 30/4,5; A369/3,4,9)	Strong fine SK	Mesokurtic	Very poorly sorted
Fluvioglacial gravels II (Sheepway 11/3,12/4,13/2, 3,5; A369/7; Wraxall 30/7)	Strong fine SK	Platykurtic	Extremely poorly sorted
Glacial tills I (HG/8,9; Sheepway 12/3; Gatcombe 31/13; 33/16; Wraxall 30/9)	Near symmetric	Platykurtic-very platykurtic	Extremely poorly sorted
Glacial tills II (A369/1,1,10,11; HG/7)	Near symmetric-fine SK	Mesokurtic-Platykurtic	Extremely poorly sorted

Skewness versus Kurtosis

The same combinations of characteristics result when skewness values are plotted against kurtosis, as shown on Fig. 5.6A and B. On the upper diagram, the fluvial gravels from Stidham separate into the near symmetrically skewed sands and the finely skewed Layer 4 gravels (= Group I), whereas the Group II fluvial gravels have a strong fine skewness and a leptokurtic curve. This diagram shows that they are distinguished by their relative skewness rather than their kurtosis values. This is due to the slightly better sorted nature of the Layer 4 gravels, contrasting with the Layer 5, 6, and 7 type, which have a combination of several sediment modes. The kürtosis values are of less significance here in distinguishing the deposits, since the various layers show a range of results.

Fig. 5.6B shows the spread of samples of fluvioglacial gravels and glacial tills. Again skewness is the overall differentiating factor, separating the near symmetrically skewed tills from the strongly fine skewed fluvioglacial gravels. (The Sheepway samples notably are the most strongly fine skewed, reflecting their extremely poor sorting and bimodality.)

The two graphs illustrate the distinction between the fluvial group of sands and gravels, and the fluvioglacial/glacial group. In this case it is the kurtosis values that are of the most use, with the fluvial group showing a wide range of values, whereas some of the fluvioglacial type are mesokurtic, but the majority platykurtic.

These characteristics and distinctions are specific only to the inter-relations of the Bristol samples, with no one measure being claimed to distinguish a specific depositional group. The technique would appear to be useful for grouping the sediments into similar depositional types. The sedimentary statistics, together with the field evidence of these deposits, result in certain parameters for each group of sediments, and suggest the probable environments of deposition for the Bristol Avon samples.

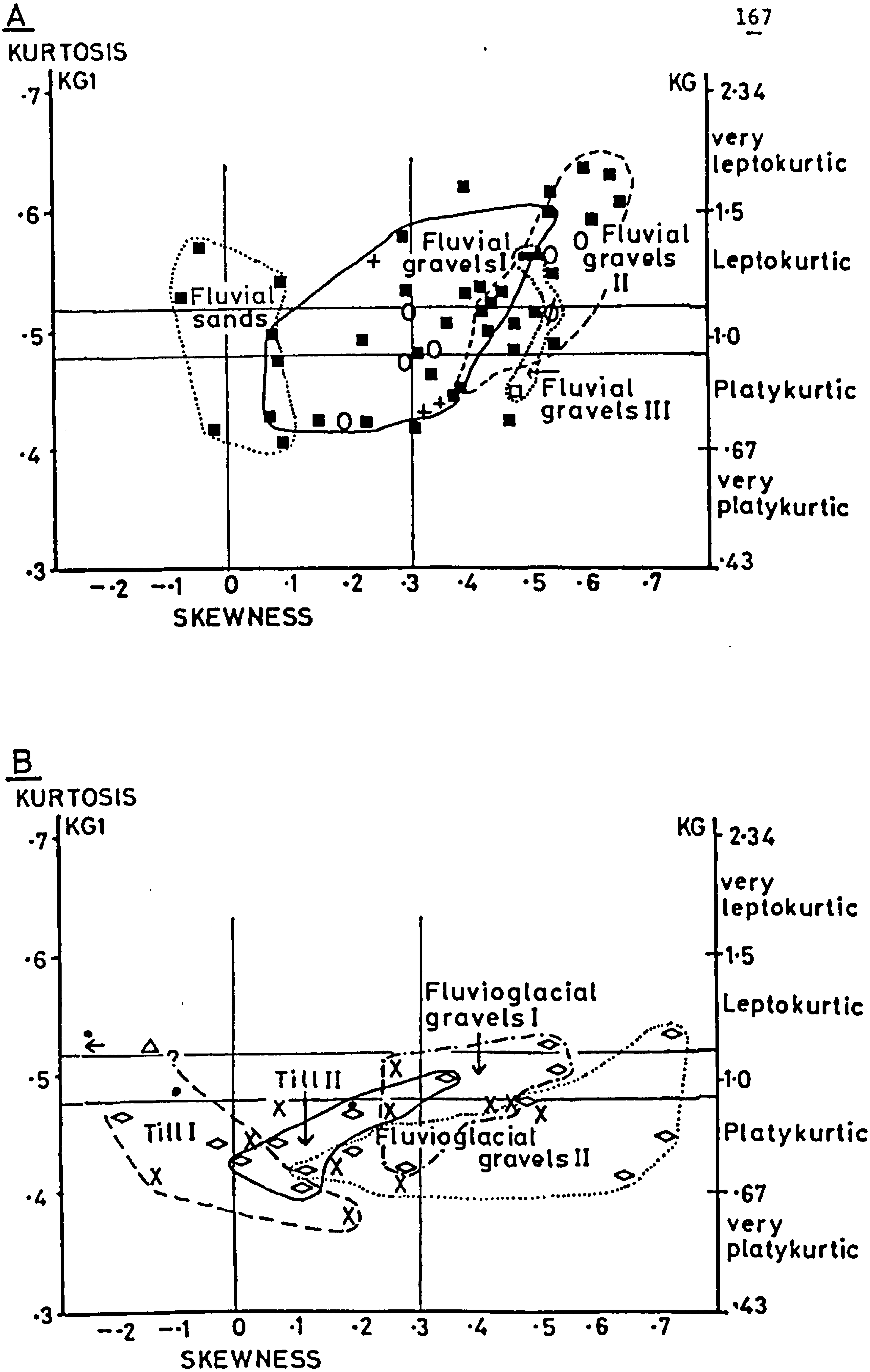


Figure 5.6 : Folk Kurtosis versus Folk Skewness

A. Fluvial sands and gravels
B. Fluvioglacial gravels and glacial tills

SECTION 2 :

LITHOLOGIES OF THE BRISTOL AVON GRAVELS :

Pebble samples from the Quaternary deposits along the Bristol Avon were separated into their various lithologies prior to the measurement of their form parameters. Pebbles of between -3 to -6ø were used for the study, since those of smaller size are often difficult to identify visually. This limitation also provides a check on any changes of lithological percentages with size. The percentages of each lithology within the samples were drawn in histograms and confirm the differences noted in the field between the typically Jurassic limestone rich fluvial gravels and the more mixed fluvioglacial and glacial deposits.

The fluvial gravels between Bath and Keynsham are shown on Fig. 5.7. Sample 14/5,8 from 27m O.D. at Bathampton is made up of 99% Jurassic limestone, and only 1% flint/chert, whereas Sample 15/3 from 21m O.D. is more mixed, with 80% limestone, 17% Jurassic mudstones, siltstones and sandstones, and only 3% flint, chert and quartz. The furthest travelled components thus represent only a tiny fraction of both samples. No distinction was made in the field between the gravels of TPs 14, 75, 19 and 15. From the drawn sections they appear to all be part of the same terrace deposit, dipping at a constant angle towards the present day river. Since the sedimentary statistics did not reveal any major differences between the samples either, then the lithological variation is the only distinguishing feature. As it only represents a slight change in the local gravel constituents, it is not considered significant enough to form the basis of a separation of the deposits.

Both the A36 and Newton St. Loe samples are similar to those at Bathampton with 75 and 86% Jurassic limestone respectively. The amount of sandstone increases to 8% at Newton St. Loe due to the inclusion of material from the local Pennant Series. As at Bathampton, the limestones were mainly Jurassic, with only 2-5% of Carboniferous.

Three sets of samples from Stidham Farm were analysed. That from Stidham A consisted of a bulk sample of 500 pebbles taken from the excavation spoil, and had 92% limestone (6% Carboniferous) and 5% flint/chert. The

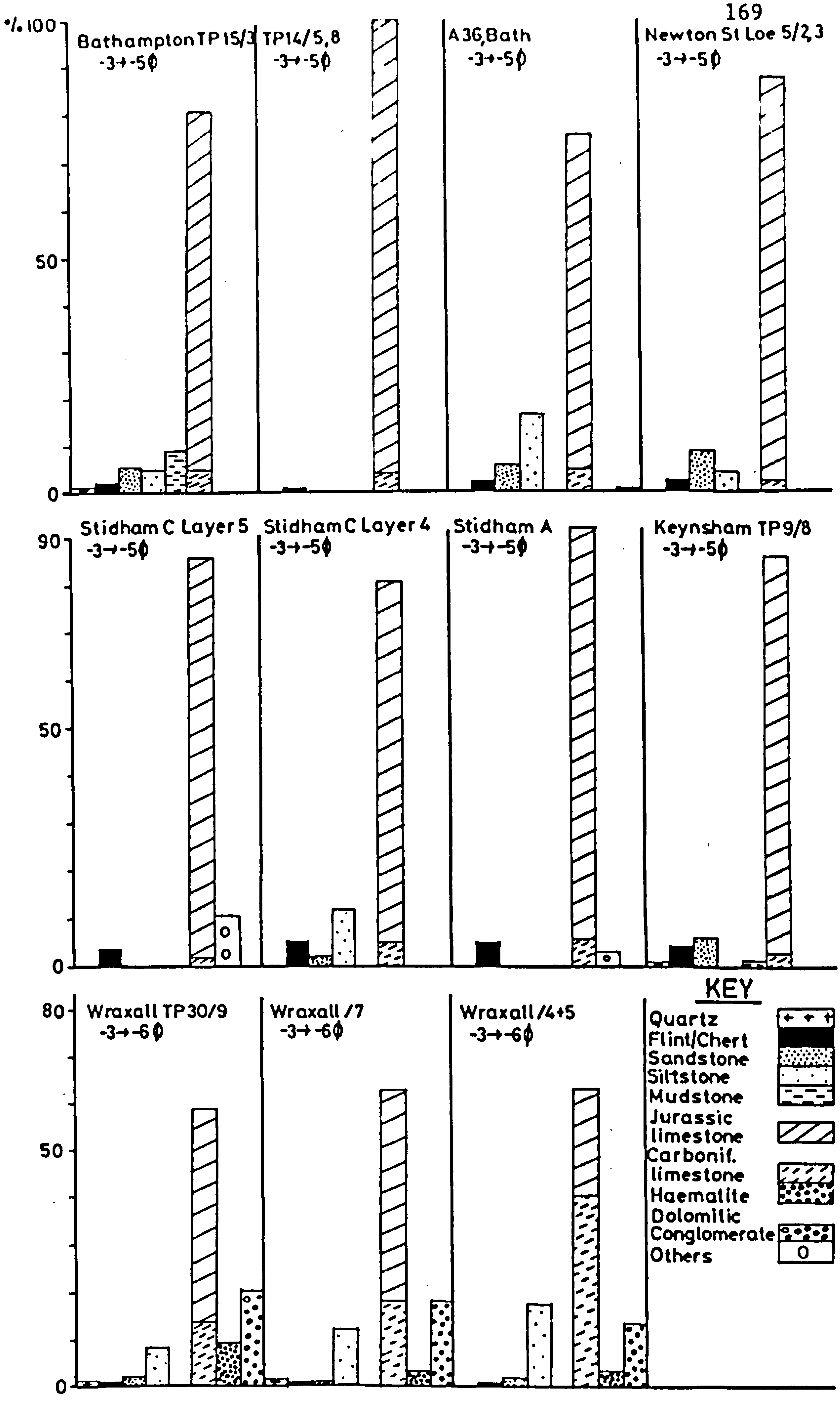


Figure 5.7 : Lithologies of the Bristol Avon gravels, Bathampton to Keynsham, and Wraxall

Stidham C samples were slightly more varied with 81% and 85% limestone from Layers 4 and 5 respectively. Keynsham TP9/8 was similar with 86% limestone, 6% sandstone and 4% flint/chert.

The five sites discussed above have roughly the same lithologies, characterised by 75-99% Jurassic limestone. The only far travelled constituents are of Cretaceous Chalk and Greensand Chert, which increases in importance downstream, from 1-2% at Bathampton, 2% at Newton St. Loe and the A36, to 4-5% at Stidham. It is notable that in the Bristol Museum amongst the Fry collection of material is a shark's tooth (Carcharodon) found at Holm Mead Lane, Bitton, by the old gravel pit. This derived fossil is common in the Bracklesham Beds (Eocene), of which the nearest outcrop lies some 60 miles south east in the Hampshire Basin.

The results from the other sites contrast with those from the fluvial gravels. Samples from Wraxall (TP30) are obviously influenced by the local geology in the same way as those at Bathampton and Stidham. Sample TP30/4,5 has 63% limestone (41% of local Carboniferous), 18% Jurassic siltstone, and 13% Dolomitic Conglomerate clasts. Flint and chert represents only 1% and haematite 4%. Sample 30/7 at the base of these main gravels showed the same overall carbonate content, but an increase in the Jurassic limestone percentage to 45%. The amount of Dolomitic Conglomerate also increases, while that of Jurassic siltstone falls, and flint, chert and sandstone remain constant. These trends are continued in Sample 30/9, which was interpreted as a glacial till. It contains the least amount of limestone (59%) (14% of Carboniferous age), while the percentage of Dolomitic Conglomerate increases to 21%. The durable haematite, quartz, flint and chert total 12% of the clasts, in contrast to the 5% found in Sample 30/4,5. This reinforces the view that the mixture of lithologies in the glacial till have been reworked by fluvial action such that the material deposited by these streams contained far less of the relatively dense, heavy constituents like haematite and chert and more of the lighter carbonate material, which was also more readily available.

Fig. 5.8 illustrates the lithologies of the Chapel Pill, Brislington, Sheepway and A369 gravels. The upper four graphs show the range of results obtained from the till deposits at Chapel Pill and Ham Green.

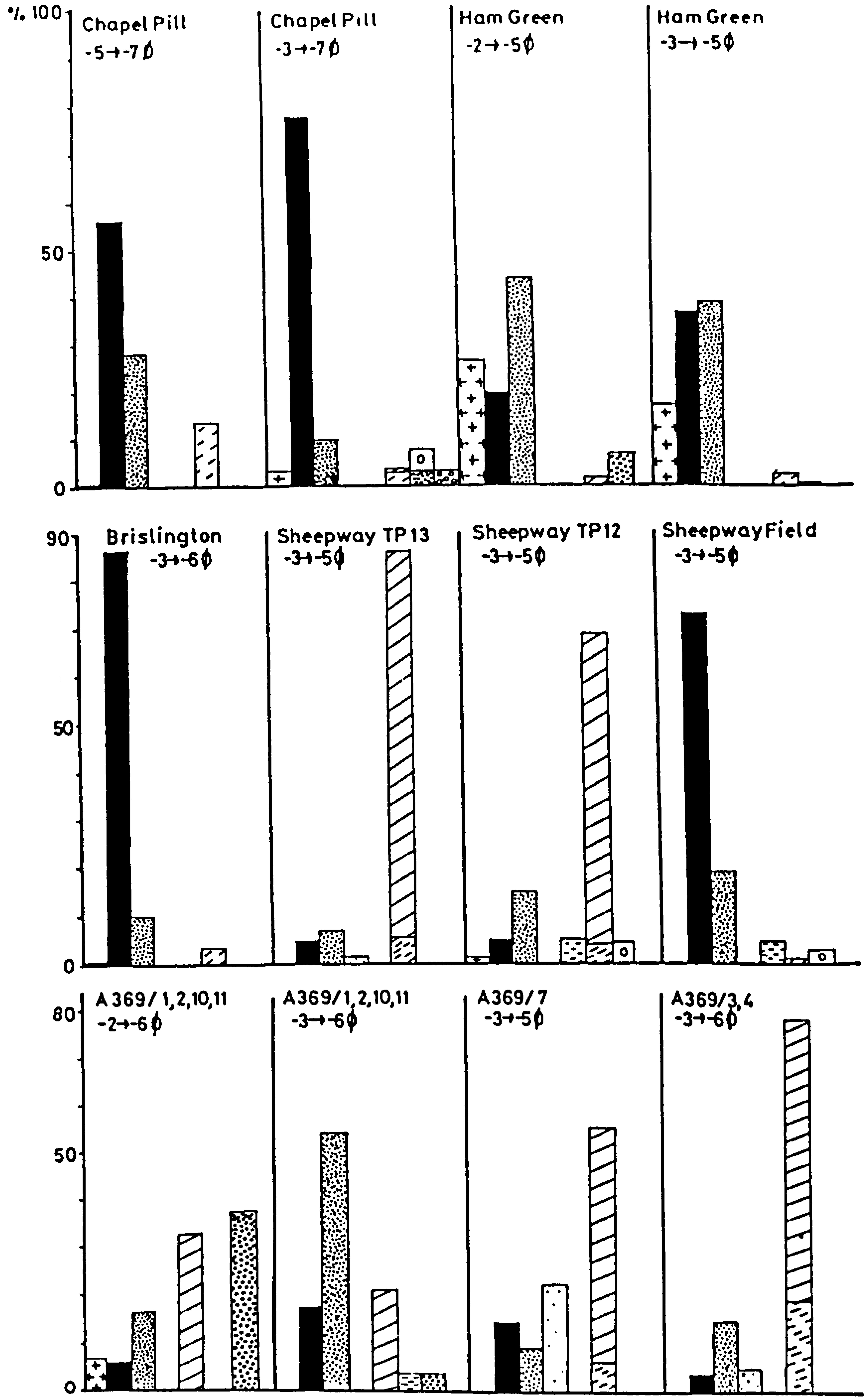


Figure 5.8 : Lithologies of the Bristol Avon gravels, Brislington, Chapel Pill, Sheepway and A369 ditch

Those from Chapel Pill consisted of pebbles from -3 up to -7ϕ. The first graph gives the results of the cobble size material (-5 to -7ϕ), and the second the percentages for the whole gravel to cobble range. The coarsest clasts consist of 57% chert, 29% sandstone, 11% Carboniferous limestone, and 1% quartz, whereas the whole sample is made up of 65% chert and 11% flint, only 9% sandstone, 3% limestone, and 11% of other lithologies including quartz, haematite and dolomitic conglomerate. Thus the largest material is limited to the three rock types of durable Greensand chert, and local sandstone and limestone. The lack of large clasts of quartz and haematite is not likely to be due to differential sorting by size, but rather the fact that haematite occurs naturally as small nodules in the local sandstone and that the quartz is far travelled material, derived from a variety of environments.

The results of the Ham Green samples are divided into those between -2 to -5ϕ and those between -3 to -5ϕ size. This is because there is an important distinction between the two size groups, in terms of the ratios of chert, quartz, sandstone and haematite. The larger size group (of medium to coarse gravel) consists of 39% sandstone and 37% flint and chert, with 18% quartz and only 3% limestone and 1% haematite. If the material of 2ϕ size is included, then the sandstone, quartz and haematite become more predominant, at the expense of the limestone, flint and chert.

The results from Chapel Pill and Ham Green are summarised in the Table below :

	Chert	Sandstone	Quartz	Haematite	Limestone
C. Pill -5 to -7ϕ	57	29	1	-	13
C. Pill -3 to -7ϕ	76	9	3	2	3
Ham Gr. -3 to -5ϕ	37	39	18	1	3
Ham Gr. -2 to -5ϕ	20	44	26	7	2

This confirms that the chert is more predominant in the larger gravel and cobble sizes, while in the medium to coarse size, chert and sandstone are of equal importance with quartz around half as frequent. In samples of fine to medium gravel, sandstone predominates, with quartz in greater quantity than chert. Carboniferous Limestone makes up 13% of the cobble size sample, falling to 2-3% of those of medium and fine gravel. The medium to coarse size sample (Ham Green -3 to -5∅) is comparable with samples from the other sites, in terms of the size range included.

The Brislington gravel sample is similar to those from Chapel Pill, with 85% chert, 10% sandstone, 3% limestone and 1% quartz. This reinforces the idea of it being a glacial material, greatly degraded (and therefore perhaps of great antiquity). This material can be defined as firstly having a cobble and coarse gravel fraction dominated by local limestones and sandstones, secondly a medium to coarse fraction in which Greensand chert and a little flint are the most prevalent, and thirdly a fine to medium gravel fraction in which haematite, quartz, and sandstone form the majority of the pebbles. In both cases, at Brislington and Chapel Pill, the large amount of Greensand chert has been utilised by Palaeolithic man for stone tool manufacturing.

The final group of samples discussed are from Sheepway and the A369 ditch. The fluvioglacial gravels (Groups I & II) all have a similar composition, with Jurassic limestone predominant and ranging from 69 to 86% of the samples. The second largest component is local sandstone (Pennant and Old Red Sandstone), while flint and chert makes up only 3-5%. The A369/7 sample (possibly a redeposited till) differs from these in having 55% limestone plus 21% Jurassic siltstone. The sandstone content is only 9% but the flint and chert amount has increased to 15%, three times that found in the gravels above. This is indicative of redeposition of a till material, rich in flint and chert clasts.

The upper red brown glacial till is radically different again, with only 20% limestone, but 18% flint and chert, and 54% sandstone. The deposit has already been considered to consist of glacial material with the possible addition of some coversands by cryoturbation and leaching. The percentage of flint and chert is typically diagnostic of the glaciogenic deposits at Kenn and on the Failand Ridge (Gilbertson, 1974 etc.), whilst the low amount of limestone is probably the result of intense chemical weathering in a cold environment. The sandstone is derived from the local outcrops on the Failand and Portishead ridges.

It is notable that this deposit, in contrast to the fluvioglacial gravel below, contains 5% haematite in the -3 to -6∅ range. If the -2∅ grade is included in the pebble count, then haematite represents 36% and quartz 7%. A similar result was obtained from the Ham Green glacial till, which also has seven times as much haematite in the -2 to -6∅ group as in the -3 to -6∅ group.

All the samples studied are of predominantly local lithologies, while the only far travelled material is Cretaceous flint, Greensand chert and quartz. The quartz is generally small and rounded suggesting recycling through several environments. The flint and chert pebbles however give more evidence for the history of the gravels and will now be discussed.

ORIGINS OF THE FLINT AND CHERT PEBBLES :

The flints and cherts of the Avon gravels have long been recognised as from the Cretaceous Chalk and of Greensand chert respectively (e.g. Lacaille, 1954; Donovan, 1960). Fig. 5.9 shows the outcrops of the Greensand and the Chalk to the east, together with the percentages of Greensand chert found in the Avon samples.

The percentage of Cretaceous siliceous nodules is subordinate to that of the chert in the Avon gravels (28% flint : 72% chert). The appearance of the flint pebbles gives no clue as to a precise area or level of the Chalk from which it has been derived. Various workers have attempted to link prehistoric flint tools with actual flint sources by means of atomic absorption spectroscopy (Sieveking, Bush et al., 1972; Aspinall and Feather, 1972; Ferguson, 1980). This study achieved some success, as they concluded that it was possible to characterise some of the British flint mines on the South Downs and East Anglia, using the trace element composition of their products.

The flint axes however were all made from flint carefully selected by the manufacturers from particular bands within the Chalk (Clark and Piggott, 1933), and the composition of all the flint from one locality is extremely variable. A similar analysis of flint pebbles would therefore require a huge analytical programme, even if it were possible to establish the composition of all possible sources. As a result, no detailed analysis of the origin of the flint pebbles found was possible during this study.

The same limitations apply to the Greensand chert pebbles, although a study of the Bristol Avon samples revealed the following mixture of descriptive types :

Type I

a) "Flinty" examples of compact grey-brown chert, sometimes with an outer margin of more porous, white or brown-yellow stained material.

b) Porous, light coloured siliceous pebbles similar to the outer portions of a).

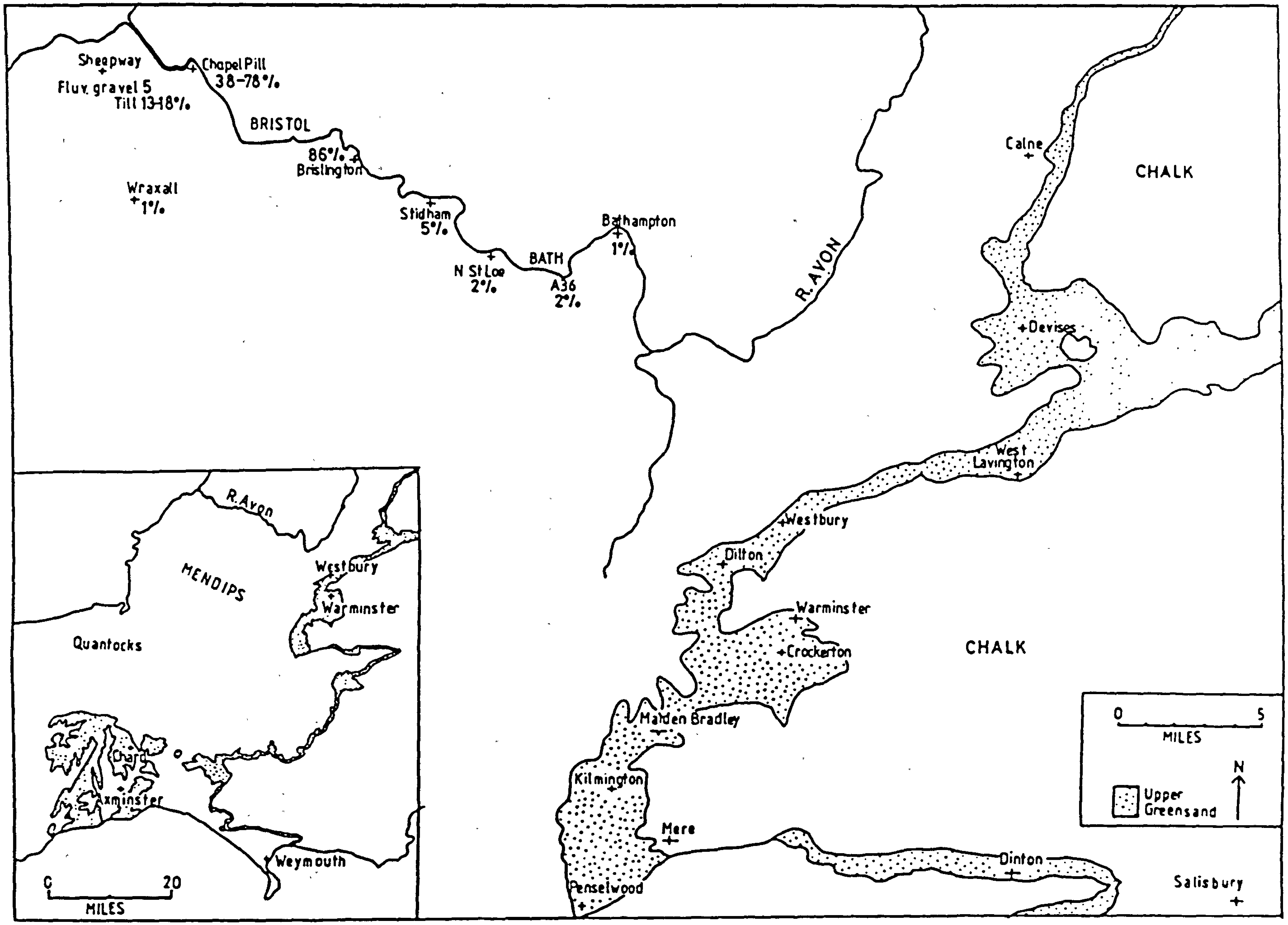


Figure 5.9:

Outcrops of the Cretaceous Greensand and Chalk, SW England, and the percentages of Greensand chert and Chalk flint from the Bristol Avon gravels

Type II
c) Honey-brown coloured, crystalline, partly translucent cherts, sometimes with an outer patina of white or cream coloured material.
d) Cream coloured pebbles consisting solely of the outer patinated layer of c).

It was decided that it would be of value to obtain examples of Greensand cherts from the various possible sources and to compare these visually with those chert pebbles from the Avon gravels.

There are two major areas of the Greensand where cherts are developed (Ramsay et al., 1858; Tresise, 1960 & 1961; Barron, 1976) :

a) between Westbury and Shaftesbury and the Vale of Wardour,
b) from Chard and Crewkerne southeast towards Weymouth.

A) Westbury to Shaftesbury and the Vale of Wardour :

A.J. Jukes-Brown (1900 & 1901), discussing the Upper Greensand, made reference to a distinction between the Warminster flinty cherts and the more opaque and sandy nodules found around the Penselwood area. This was confirmed during fieldwork.

Around Warminster, the Upper and Lower Greensands are separated by fine, grey silty sands with irregular layers of chert nodules, which have an outer white portion and an inner flinty chert core of grey or yellow brown colour. The chert dies out to the north of Westbury, with none found in the Greensand area around Devizes and the Vale of Pewsey. The present fieldwork found exposures of the Lower Greensand at :

Sands Farm Quarry, Calne (SU 014713) and between Naish Hill and Sandy Lane (ST 939694). The Upper Greensand was exposed at Dunkirk Hill, Devizes (St 996617); between West Lavington and Westbury (Kelly, 1971); at Short Street, off the A36 (ST 833487); between Dilton Marsh and Old Dilton (St 855493); Henford's Marsh Lane (ST 876441); Bore Hill cutting on the A30 at Crockerton (ST 868437). These sites all showed yellow/green/brown silty sands, but with no examples of cherts, although at Henford's Marsh Lane some white siliceous rocks were noted.

The second area of fieldwork lay between Maiden Bradley and the Penselwood to Mere area. The old quarry at Maiden Bradley (ST 795395), discussed by Jukes-Brown, is now filled in, but several slips in the backfill material revealed some examples of cherts, presumably from the quarrying. These were all of the "flinty" chert type and ranged in colours from pale grey to light brown and dark red, with an outer cream coloured margin. Jukes-Brown described the chert as having a dark chalcedonic core and an outer grey "sponge" rock, or else as being of cherty stone, with a centre of brown black chalcedony.

No modern exposures were found around the Penselwood area, where the Kimmeridge Clay abuts the Greensand along the Mere fault (Edmunds, 1938; Mottram, 1957), but at Dead Maids Quarry, Mere (ST 803324) yellow green sands were found exposed just below the Lower Chalk. These sands contain nodules and tabular lenses of dark grey black flinty cherts with a white margin. The same material was found at Zeals Trout Farm, Woolverton (ST 789315).

The third area investigated was in the Vale of Wardour. Unfortunately the exposures at West Knoyle and Ark Farm, Ansty were no longer visible, and at Fir Hill, Fovant (SU 006297) the fossiliferous Greensand was found but contained no chert. At Field Bank Lane, Dinton (SU 009322) there was some chert development in the form of concentrations of siliceous material, forming lithified nodules.

B) <u>From Chard - Crewkerne to Weymouth</u> :

These chert beds contain both the cored chert found to the north and discussed above, and a second type, which is honey brown in colour and originally formed in irregular masses. It was predominantly this honey coloured chert that was used to make the Palaeolithic tools commonly found in the Axe Valley of Dorset (Green, 1947; Roe, 1981). The insert map of Fig. 5.9 shows the outcrops of Greensand chert around the Chard area.

The Bristol Avon samples contained cherts of both types, which are now named : Type I - the "cored, flinty" chert and Type II - the honey brown, grainy chert. The Chard-Axminster area is the source of both types, whereas the Westbury-Vale of Wardour area contains only type I.

The relative percentages of Cretaceous flint, Greensand chert Types I and II that are found in the Avon gravels are shown in Fig. 5.10. From this diagram it can be shown that in the main terrace gravels between Bathampton and Stidham, Cretaceous flint dominates the far travelled material, with Type I chert approximately twice as important as Type II. The total of flint and chert in these deposits however is only c. 2% rising to 5% at Stidham, so that the relative importance of the far travelled material is small compared to the sites downstream at Keynsham.

At Brislington no Cretaceous flint was found, while at Chapel Pill it was present in very small quantities. At both sites however Type I chert made up c. 60% of the flint and chert total, with 40% of Type II. In the Sheepway trial pits the relative percentages of the cherts were closer (e.g. in TP12 only 5% of the total gravel was made up equally of Types I and II). In Exposure 2, 44% of the total gravel consisted of 54% Type I to 44% Type II.

The sandy gravels of the A369 ditch contain solely Type I chert, but the redeposited till beneath (A369/7) had a greater percentage of far travelled material, with 66% made up of Type I chert to 33% of Type II chert.

Hence the suggested glacial till deposits (Chapel Pill, Brislington) have the same ratio of Type I and II cherts (about 3:2). The fluvial/fluvio-glacial gravels that are possibly derived from these tills have more of a balance between the two chert types. The upstream terrace gravels contain more Cretaceous flint than chert, and the percentage of flint decreases in a downstream direction.

A third source area or deposit for the Greensand chert contained within the Avon gravels (other than directly from the Westbury or Chard areas) is suggested by the downstream increase in the % of Greensand chert found in the terrace gravels (Fig. 5.9). This points to a westerly source,

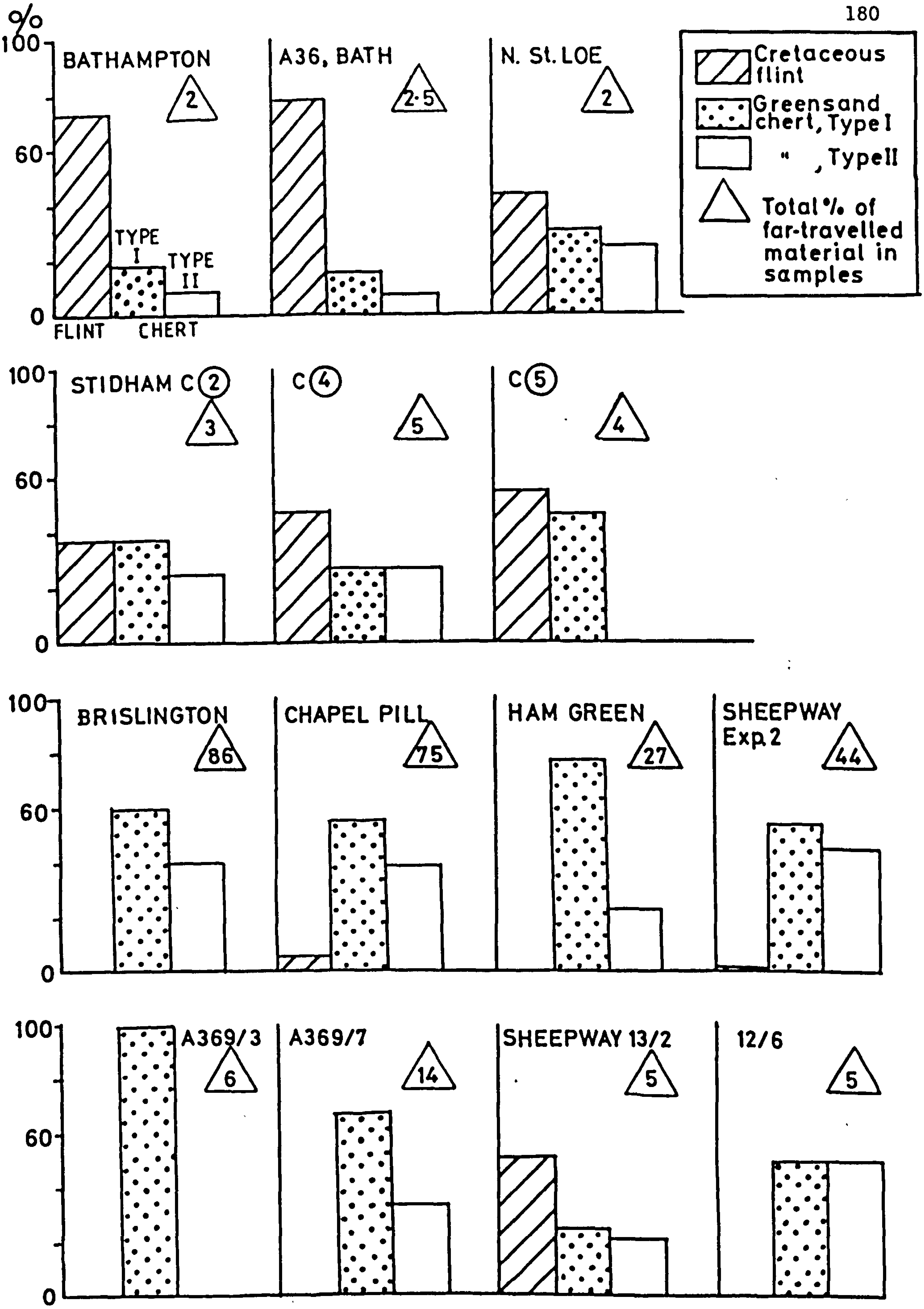


Figure 5.10 : Relative percentages of Chalk flint, Greensand chert Types I and II, in the Bristol Avon gravels

which could be either from older chert rich deposits e.g. at Brislington and Chapel Pill, or else similar deposits brought in from the Bristol Channel by ice. Chert rich gravels are known to exist on the islands of Lundy, Flat Holm and Steep Holm and on the bed of the Bristol Channel (Lloyd et al., 1973). Studies of the submarine geology of the Celtic Sea suggest that while the Chalk is widespread from the English Channel north towards St. George's Channel, it does not extend into the Bristol Channel itself (Smith et al., 1965; Curry et al., 1967; Hamilton and Blundell, 1971). The Celtic Sea is therefore a likely origin for the Chalk flints and presumably also the Greensand cherts, which have been transported westwards from their original source by glacial ice, and left as the diagnostic erratics of the known tills of the Somerset area.

Conclusions :

It appears likely that the Cretaceous flint found in the terrace gravels is derived directly from the Cretaceous beds to the east. Some of the Type I chert will also have come from this area. The amounts of these materials decrease in a downstream direction with distance from their source.

The chert content of the Avon gravels consists of various amounts of Types I and II, both of which are found in the Chard region of Dorset. About 50 miles distance and the range of the Mendip Hills divide this source from the Lower Avon Valley, hence it is more probable that the cherts were derived from sources to the west, in the Bristol Channel and Severn Estuary and were brought inland by ice. This theory is supported by the large percentages of Greensand chert in the glacial deposits at Chapel Pill and Brislington and the increase in the amount of chert in the terrace gravels in both a westerly and a downstream direction.

SECTION 3 :

MEASUREMENT OF SIZE AND SHAPE OF THE GRAVEL PEBBLES :

Introduction

One important aspect of the depositional history of the Avon gravels is the size and shape of the component pebbles. The results of this work will be considered below but it is appropriate to discuss first the reasons for and merits of the methods used.

The analysis of particle morphology has been much debated amongst geologists. Interest in the study resulted in a wealth of literature in the 1930s and 1940s in particular, e.g. Wadell, 1932, 1933; Wentworth, 1933; Zingg, 1935; Krumbein, 1941a & b; Cailleux, 1945. These workers laid the basis of the study and described the concepts of shape, roundness and sphericity. Through the 1960s and 1970s Folk and his co-workers established parameters that were suggested to relate to a particle's behaviour and environment, rather than being simple shape classifications, e.g. Maximum projection sphericity and the form triangle (Sneed and Folk, 1958); Modified Wentworth roundness and oblate-prolate index (Dobkins and Folk, 1970).

The major problem besetting each worker is to give a realistic assessment of a natural pebble, with all its variables and uniqueness, in terms of a few geometric measurements. All the accepted parameters lack ability to describe some particular aspect of a pebble. Furthermore, it may be questionable whether the measures are directly affected by environment and transport, or whether they are more related to parent rock type and size.

Many early studies assessed pebble roundness by observation as opposed to direct measurement, which raises the question of objectivity and repeatability by observers and between workers. In the present study, it was decided to concentrate on parameters derived from direct measurement, so as to allow some comparison with other studies. At the same time the usefulness of visual comparisons with standard charts of pebble shape was realised; this may go some way towards assessing the "immeasurable" aspects of individual pebbles.

A comparison of the results of measured sphericity against visual sphericity shows the difference between the geometric approach and the more subjective method.

In deciding which measures to use, a study of the literature revealed the wide range of possibilities. An excellent summary of these is made by Barrett (1980), who defines the various parameters and their usefulness.

"Shape" has been interpreted in a multitude of ways, but fundamentally combines the three aspects of form (also termed sphericity, 3d shape, elongation, and flatness), secondly roundness (angularity and aspects of the edges and corners of a pebble), and thirdly, surface texture (small scale features and marks). Each worker has used those features of importance to him and his particular samples. At times, this is a necessary discrimination.

METHODS OF MEASUREMENTS :

During the present study, five observations were made on each pebble. The first three are direct measures of the long, intermediate and short diameters, made with a set of calipers, with a Vernier scale to two decimal places. The longest diameter is taken first, the intermediate at right angles to this, and the short at right angles to the first two. There are some cases when the first visual impression of the long diameter is not actually the maximum axial length; such problems are especially found with pebbles from the elongate shape class. Since the measures are used to calculate the area of the maximum surface of the pebble (which controls how the pebble behaves in motion) then it should be the longest axial length that is taken as the first measure.

The measures give the "diameters" of the three planes of the pebble shape. From these the ratios of a (long axis) to b (intermediate) to c (short) are computed and used to produce :

a) pebble form on a triangular diagram (Sneed and Folk, 1958). This plots $\frac{c}{a}$ and $(a-b)/(a-c)$, to give an assessment of form in relation to the three end members of compact, platy, and elongate shape.

b) maximum projection sphericity (Sneed and Folk, 1958). This is the ratio of a sphere equal in volume to the particle, to a sphere with the same maximum projection area, and relates to how the particle behaves during transport.

c) oblate-prolate index (Dobkins and Folk, 1970). This defines whether the intermediate axis is nearer in size to the long or short axis (with account taken also of the relation of long to short, which further limits the groupings). Disc shapes have a negative oblate-prolate index (b axis closer to a), while rods have a positive OP (b closer to c). Perfect blades give an OP of zero.

d) % elongation (σ) : This represents the percentage of b (intermediate) to a (long), where 100% σ would equal a sphere or square shape, 75% σ equals a pebble that is distinctly rolled around the long axis, and 50% σ equals a needle shape that is twice as long as it is broad.

The four measures above can be used to produce 2 triangular diagrams showing :

1) pebble form
2) Maximum projection sphericity versus oblate-prolate index.

The drawback of this is that a trend found on one graph cannot be independently confirmed from the other as they are both based on the same data. Previous studies (Barrett, 1980) have shown that the distribution of maximum projection sphericity and OP index is normal and is effective in discriminating between different pebble shapes.

It should be noted that these measures cannot take account of shapes subordinate to the three axes, e.g. a pentagonal shape could have the same measures as a rectangular one. Although to a great extent these shapes are controlled by parent rock type and its discontinuity geometry, it is a valuable aspect to record.

The additional two measures made on each pebble were visual ones, made from chart comparisons, and based originally on the work of Krumbein (1941) and Powers (1953). Outlines of pebbles ranging from low to high sphericity and angular to well-rounded were drawn in the form of a square chart, which was then successively enlarged to provide a set of charts ranging from a diameter of 8mm to pebbles of 80mm. This made the visual comparisons easier, by using images of roughly the same size as the sample pebbles.

This visual measure goes some way to overcoming the deficiency of the three orthogonal measures, which failed to separate shapes with few sides (triangular and rectangular) from those with more sides (pentagonal and hexagonal).

The final measure is of visual roundness, which considers the state of the corners and edges of a pebble. The argument as to whether roundness is independent of sphericity, which raged between Wadell (1932) and Wentworth (1936), is partly resolved if sphericity is seen as only a part of the definition of overall shape/form, whereas roundness is a detailed parameter of smaller scale aspect, i.e. the edges and corners. No quick and easy way has been found of measuring roundness directly. Most involve measuring the curvature radii of the corners of a pebble. Wadell's (1932) method measured each corner of the maximum projection outline (generally between 2-6 corners). The diameters of these are averaged and divided by the maximum inscribed circle, to provide a measure of average roundness.

Such a method involves much time and calculation for each pebble, so the prepared roundness charts were again used (Krumbein, 1941 and Powers, 1953). Although the disadvantages of subjectivity arise, there is the advantage of visually summarising all corners in 3d (as opposed to Wadell's 2d measure). Barrett (1980) studied the range of methods of measuring roundness and in tests found the chart method gave results close to a normal distribution. In the present study the roundness results were plotted against the % elongation (σ) to give a further graph showing pebble form.

The factors which decided the choice of shape measures were effectiveness (repeatability over a range of pebbles and closeness to a normal distribution) and speed (some 8000 pebbles from 27 samples were measured). The actual technique involved spreading the sample on a tray and separating the pebbles into lithological types. The original particle size samples were used, but where these contained too few pebbles another subsample had to be washed. The material was sieved to remove the fraction finer than -2ϕ, since these pebbles are too small to be easily recognised lithologically by eye alone. When measuring,the rock types were kept separate and divided into three groups of greater than -5ϕ, -4ϕ and -3ϕ. This controlled any variability of shape with size, and also provided data on how lithology varied through the size distribution (Burke and Freeth, 1969; Caldwell, 1983;

The measurements were made with a set of calipers and recorded on sheets in five columns, ready for computation. A programme was used to calculate interaxial ratios, maximum projection sphericity and the OP index, together with the means and standard deviations of pebble size, visual sphericity, and visual roundness. The results were produced in the form of tables and histograms, an example of which is included in Appendix IV. The "sphericity test" programme was compiled by R.K. Lewis of the Sedimentology Laboratory of the University of Bristol, and his work is gratefully acknowledged.

RESULTS OF THE MEASUREMENT OF SIZE AND SHAPE OF THE BRISTOL AVON GRAVELS :

The principles involved and techniques used for these measurements have already been discussed above : the results will now be considered.

The computation of the measures of the three principal, orthogonal diameters and the visual comparisons of sphericity and roundness of each pebble produced a print out of the following :

a) mean longest diameter
b) maximum projection sphericity
c) Ratio I $\left(\frac{\text{short diameter}}{\text{long diameter}}\right)$
d) Ratio II $\left(\frac{\text{long-intermediate diameter}}{\text{long-short diameter}}\right)$
e) visual sphericity (ψ)
f) visual roundness (ρ)
g) oblate-prolate index (OP)
h) elongation index (σ)

From these results the following graphs were drawn :

Fig. 5.11 Mean pebble length versus standard deviation (to show whether the various samples are directly comparable, and the significance of the size of the material in the different depositional environments).

Fig. 5.12-5.15 Form triangles of Ratio I (compactness) versus Ratio II (platy, blade or elongate shape) (Sneed and Folk, 1958).

Fig. 5.16 Cumulative frequencies of maximum projection sphericity for each rock type at each site.

Fig. 5.17 Results of Student's t-tests on the maximum projection sphericities, showing samples from similar and differing populations.

Fig. 5.18 & 5.19 Triangles of OP index versus Maximum projection sphericity (Dobkins and Folk, 1970). This further distinction between rod, blade and disc shapes and the MPS, concentrates the pebbles into groups which will behave similarly when in motion.

Fig. 5.20 Cumulative frequencies of elongations of pebbles - similar to the OP index, dividing into the needle-shaped, rolled and spherical groups.

Fig. 5.21 Visual roundness versus visual elongation - combining the roundness of the corners and edges with the roundness of overall shape.

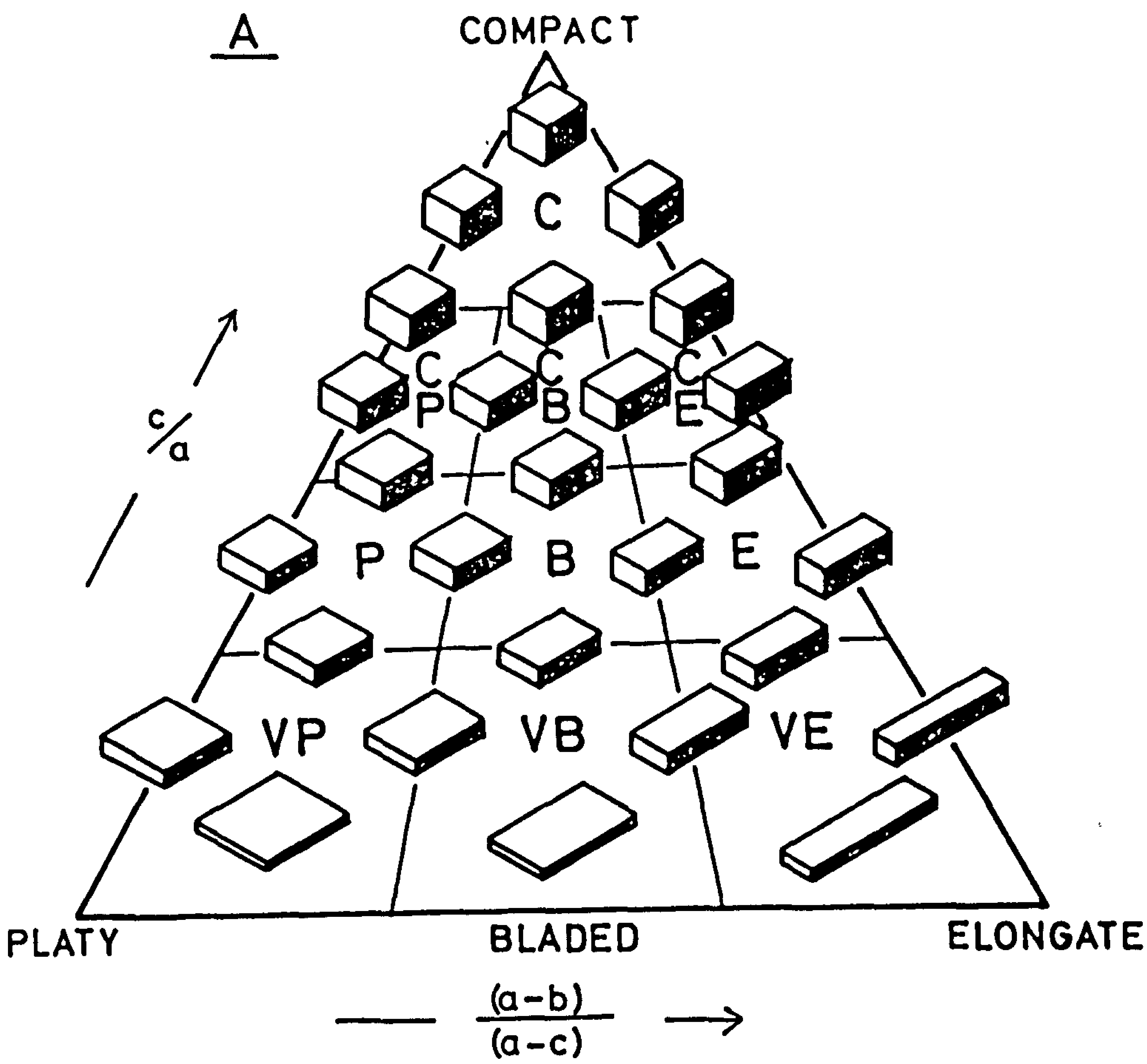
As a rule little information could be obtained from the Jurassic, Carboniferous limestones and sandstones, since they are too soluble or too naturally variable to retain useful evidence of environmental shaping or sorting. The rocks that were of most use tended to be the compact, isotrophic varieties such as flints, cherts and haematite.

1. Mean Pebble length : (Fig. 5.11) This shows the results for the major rock types found. The diagram shows that the gravel from Chapel Pill and Brislington tends to be slightly larger than that from the other sites and that the standard deviation of the samples increases with size i.e. the sorting of the pebbles by size is less effective as the gravel becomes larger. The most important fact to emerge from these diagrams is that in any comparison of the later results of pebble measurements the slightly larger clast size and the less sorted nature of the glacial tills should be taken into account. These results correlate with the findings of Davis (1958); King and Buckley (1968).

2. Form Triangles : (Figs. 5.12 - 5.15) These illustrate the relation between the three axes of a pebble so that they can be classed into ten shape categories as shown on Fig. 5.12, while Figs. 5.13 - 5.15 show the details of each rock type at each site. As noted earlier, the results from the compact, isotrophic rocks are of most use, since lithology, solubility, and natural variability are of lesser importance than environmental controls in determining the final pebble shape.

The Cretaceous flints from Bathampton to Stidham are predominantly platy to bladed, with some very platy shapes. These shapes are very likely to be controlled by the breakage planes of the resistant parent rock, and the pebbles may only have travelled some 20 miles from their source in the Chalk.

Figure 5.11 :
Mean pebble length versus standard deviation of the Bristol Avon gravels



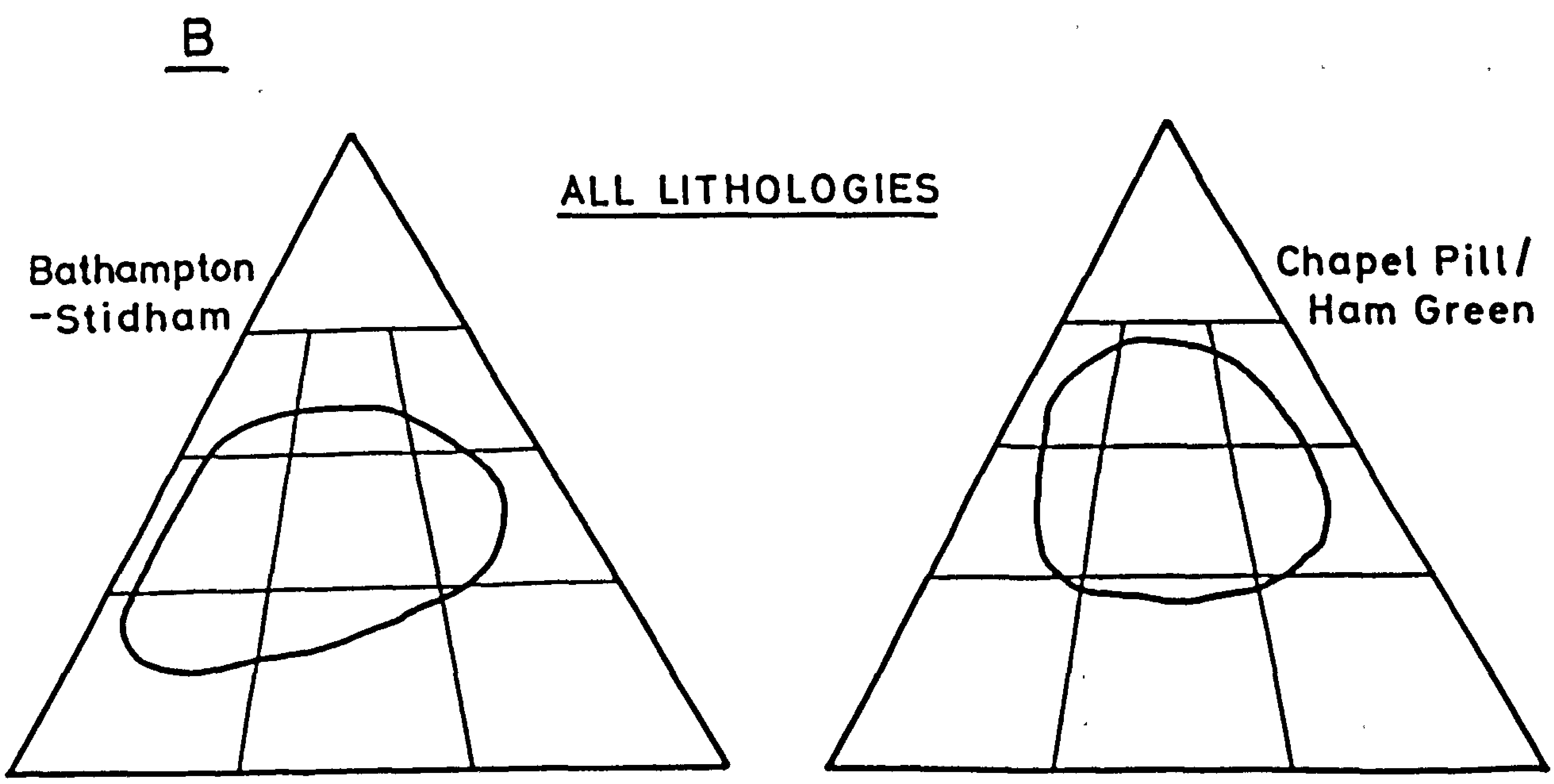


Figure 5.12 : Form triangles of Ratio I : Ratio II.

A. Form categories
B. Results for all lithologies

Fig. 5.13


CHERT I
Brislington
CHERT II
Bathampton
+ Stidham
CHERT I
• Sheepway 13/2
• A369/3
o Stidham
CHERT II
Brislington
CHERT I
• Chapel Pill
× Sheepway Ex. 2
CHERT II
• Chapel Pill
o Ham Green
FLINT
• Bathampton + Stidham
o Chapel Pill
CHERT II
• Sheepway
o A369

The examples of flint from the Chapel Pill deposit however show no platy characteristics but are all of bladed shape with a slight tendency towards elongate and compact types. The shapes of the flint pebbles perhaps suggest that platy shapes will settle towards the fluvial stream bed easier, while the glacial environment tends to produce, or selectively sort, the more rolled and rodlike types.

The Greensand chert Type I pebbles are predominantly bladed, but while those from the sandy gravels at Sheepway and the A369 ditch include some from the platy and very bladed categories, those from Chapel Pill include also the elongate and compact shapes. The Type I chert from Brislington is very similar with 50% bladed pebbles and a subequal amount of platy and elongate examples. This may reflect again the tendency of the more platy shapes to settle out of the turbulent transporting medium and to resist further movement, while the glacial deposits contain a range of pebble shapes but with a tendency to the compact forms.

The Type II Greensand cherts of the terrace gravels between Bathampton and Stidham are bladed with a tendency towards the elongate shape class. The sandy gravels at Sheepway are similarly placed but contain also a number of the platy and compact groups of shapes.

The glacial pebbles from Chapel Pill show stronger tendencies towards the compact-platy and compact-bladed groups, although as always the majority are bladed. This trend is seen again, to a lesser extent at Brislington. The Sheepway group are therefore intermediate between the bladed-elongate, true terrace material, and the glacial bladed-compact pebbles. Hence they show that fluvial transport has a tendency to sort or shape and deposit more elongate-rod like shapes of chert. This contrasts with the flint pebbles which tended towards the more platy shapes in the terrace gravels and the more elongate ones in the glacial deposits.

The haematite pebbles from TP30 at Wraxall are mainly bladed to compact-bladed, while those at Ham Green are more limited to the bladed group, with some tendency towards platy and compact-platy, although since these pebbles are very close to their source rock, their original nodular shape within the sandstone may be the strongest controlling factor.

The wide range of shapes from the Carboniferous Limestone from Sheepway illustrates the weakness of environmental control of limestone pebble morphology compared with their solubility. The most useful aspect of the Carboniferous Limestone is in the comparison of very local changes in pebble shape in areas close to the source rock, e.g. at Wraxall TP30 : here the limestone pebbles from Sample 30/9, the glacial till, are bladed to very bladed, with subequal amounts of platy and elongate types. The fluvioglacial gravels above this however show a trend towards the platy and compact groups instead of the very bladed types. This is interpreted as a tendency for the streams to transport and deposit the flatter or squared pebbles rather than the extreme rod like shapes, which may have been carried further.

The same lithological limitations apply to the Dolomitic Conglomerate pebbles found at Wraxall, which again are not good indicators of environmental shape control over long distances. While the glacial Dolomitic Conglomerates of TP30/9 show a very varied range of morphologies from platy, through bladed to compact, the fluvioglacial group is more limited and lacking in examples of the pure platy and pure compact types, so that the stream environment has here selectively sorted or shaped the more rod-like types.

The final rock type studied was the sandstone, which obviously ranges in lithology and hence resistance between the Old Red Sandstone, the Carboniferous and the Pennant types. The admixture of the various types at some of the sites and the difficulty of identifying some of the smaller pebbles, together with the strong lithological control of shape (e.g. the compact siliceous sandstone compared to the platy, fine sandstones) meant that the best use is made of the shape data if comparisons are made between the deposits at any one site : e.g. the sandstones of the sandy gravels of the A369/3,9 which are platy to bladed with some very platy and very bladed examples, compared with those from A369/7, the redeposited till, which tend strongly towards compact bladed groups. Broadly speaking the sandstones of the terraces between Bathampton to Stidham are more platy than the glacial sandstones of Brislington and Chapel Pill which are compact, bladed or elongate.

Fig. 5.14


SANDSTONES
Bathampton+Stidham
CARB. LIMESTONE
• A 369/3
o Sheepway13/2
o Brislington
x Chapel Pill
• Ham Green
CARB. LIMESTONE
• Wraxall TP30/4
o " " 30/9
• A369/3+9
o " /7
HAEMATITE
• Wraxall
o Ham Green
Sheepway13/2
DOLOMITIC
CONGLOMERATE
x Wraxall TP30/4
• " 30/7
o " 30/9


Fig. 5 15
Bath-Stidham
Brislington
Wraxall
Chapel Pill
Sheepway
CHERT I
CHERT II
FLINT
HAEMATITE
CARB.
LIMESTONE
30/4
30/9
13/2
DOL.
CONGLOM.
30/9
30/4
SANDSTONE
A369/7
13/2
A369/3

The lower triangular diagrams of Fig. 5.12 summarise all the pebble results, by contrasting the predominant shapes of the pebbles of all rock types from the terrace gravels, with the shapes of the pebbles at Chapel Pill and Ham Green. Both groups are most commonly bladed but the tendency of the terrace material is towards the platy shapes, while that of the glacial pebbles is towards the compact or elongate types.

3. Maximum projection sphericities : (Fig. 5.16) The diagram gives the cumulative frequencies of the results of the more resistant cherts and flints, and in contrast, those of the relatively soluble Carboniferous Limestone. The limestone shows the widest range of sphericities, and the majority (from Wraxall, Sheepway and the A369) have a similar trend of c. 80% with a maximum projection sphericity (MPS) of less than 0.7 (where a perfect sphere = 1.0) and a range of 0.35 - 0.85. In contrast, the Stidham pebbles range from 0.45 to 0.85, while the Ham Green and Chapel Pill examples stand out from the rest as having the higher sphericities. Even if this is due in part to the slightly larger size of the Chapel Pill pebbles, the Ham Green examples are of similar size to the other Carboniferous Limestones and yet 78% are limited to sphericities of 0.5 to 0.7. This limitation of forms may illustrate the very local nature of the limestone at Ham Green and Chapel Pill, with the glacial material not moved far from its source, while the fluvial and fluvioglacial gravels show a tendency to a wider range of more flattened and elongate pebbles due to the longer transportation and the susceptibility of the limestone.

The Cretaceous flints from Bathampton have a wider range of sphericities than those transported further downstream to Stidham and Keynsham, while the Chapel Pill flints are far more spherical.

The Type I cherts are all of similar sphericity ranges and do not seem to reflect the varying deposits, although the Chapel Pill pebbles are more spherical. The Type II cherts are of more use in differentiating the deposits with the least sphericity shown by the Bathampton to Stidham examples graduating to the Sheepway gravels and the most spherical examples at Brislington, Ham Green and Chapel Pill. This rock type would appear to reflect most closely the effects of the different transporting mediums.

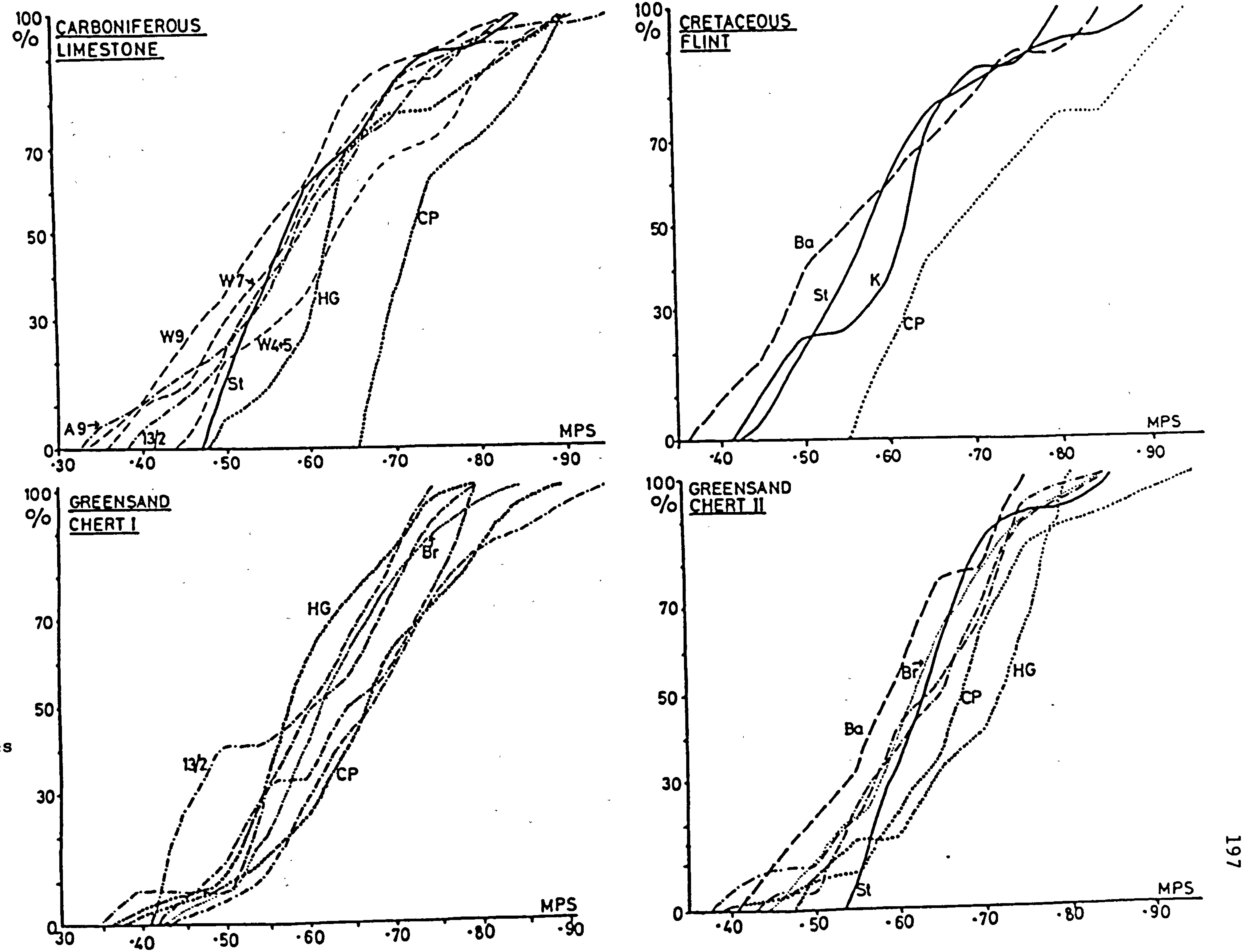


Figure 5.16 :

Cumulative frequency curves of Maximum projection sphericities for the various lithologies and sites

4. Student's t-tests on results of maximum projection sphericity :
To test whether there is a true difference of sphericity between the samples, a statistical measure of population similarity, known as the Student's t-test, was used. Fig. 5.17 shows the results of the t-tests on the MPS of the samples, giving the mean of each sample along with the possible range of means of that sample's population. These means were then used to compare the various samples by a t-test.

The results of comparing the distributions of MPS of the Cretaceous flint show that the Bathampton, Stidham and Keynsham samples come from the same population, while the Chapel Pill pebbles are from a different one. Again this may be related to size or the relatively small numbers of pebbles in the terrace gravel samples, leading to a wide range of possible means for their populations.

The chert Type I samples class Sheepway Exposure 2 and Chapel Pill as the same population, but a different one from that of the Brislington and Ham Green samples, and those from the sandy gravels at Sheepway and the A369. Brislington and Ham Green are from the same population however, This may be explained by the Chapel Pill cherts being larger, but on Fig. 5.11 they are seen to have a mean size similar to those from Stidham, while those from Brislington are larger still. The Sheepway Exposure 2 pebbles were very close in size to those from the Sheepway, A369 and Ham Green sites. Since the Stidham pebbles are found to be from the same population as Ham Green, Brislington and Chapel Pill then the chert fails to be significantly different at the various locations.

The chert Type II samples give the pebbles from Bathampton as from a different population from those at Chapel Pill and the A369/7. The small numbers of pebbles, from Stidham and the Sheepway sandy gravels lessens the viability of the results from these sites. As a whole most of the chert Type II pebbles are from the same population.

The haematite, Dolomitic Conglomerate and quartz pebbles all have means that lie within the same population ranges.

The results of the t-tests therefore show that the range of MPS values for the various lithologies is generally the same at a 95% level of

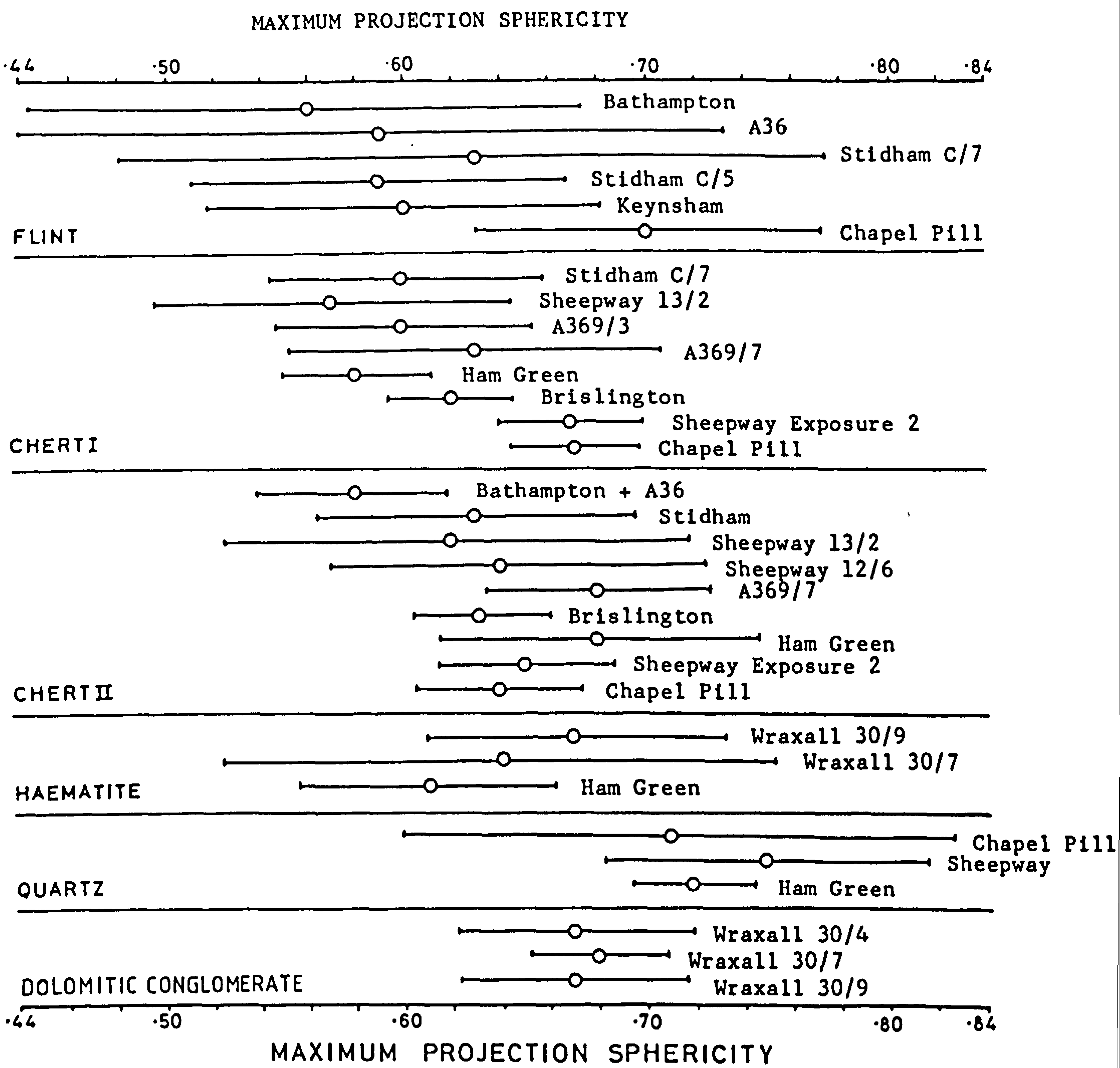


Figure 5.17 : Results of Student's t-tests on the Maximum projection sphericity data, showing Mean of each sample (o) and the possible range of Means of that sample population

significance i.e. there is a 95% certainty that they are from the same population. The only exceptions to this are that :

a) the Chapel Pill flint differs from the terrace gravel flints,
b) the Sheepway Exposure 2 and Chapel Pill Type I cherts are different from the Brislington and Ham Green examples,
c) the Bathampton and A36, Bath Type II cherts are different from those of the glacial deposits at Chapel Pill and the A369.

5. Oblate-prolate Index versus Maximum projection sphericities : Figs. 5.18 and 5.19 are a further development of the form triangles, and plot the oblate-prolate index against the MPS. The individual pebble plots have been contoured to show the distributions of 75 and 95% of the pebbles.

The Cretaceous flint, as seen already from the form triangles, shows a difference of distribution of the terrace gravel and Chapel Pill pebbles, although here the Chapel Pill flints are not solely confined to within the area of the terrace gravel samples. They include bladed, compact-bladed and compact-elongate types, whereas the terrace gravels show few compact forms and range to very platy and very bladed examples. Compactness continues to be a feature of the glacial pebbles, while platiness is a characteristic of the fluvial terrace gravels.

The Carboniferous Limestone pebbles of Wraxall and Sheepway show similar distributions, with few compact examples, in contrast to those from Chapel Pill. The sandstones form a very mixed group due to a combination of the various lithologies, differing resistances and different environments.

The Type II cherts progress from the elongate and very bladed forms on the periphery of the Sheepway sandy gravel distribution, through the platy, bladed and elongate range of the Brislington examples, to the Chapel Pill group, which include many compact forms. If only the 75% contour is drawn, then this progression from elongate, through bladed to platy and compact platy is confirmed.

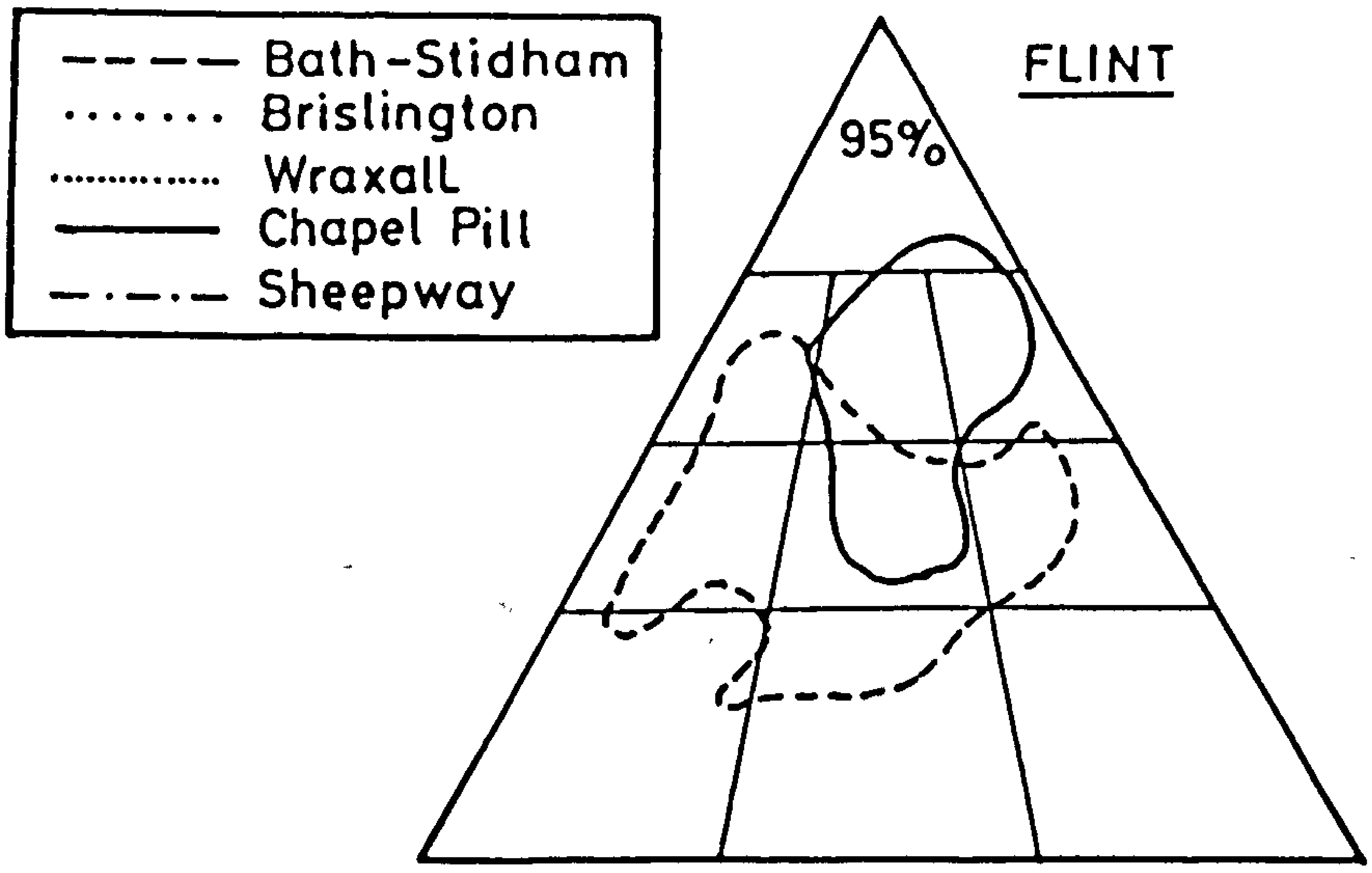
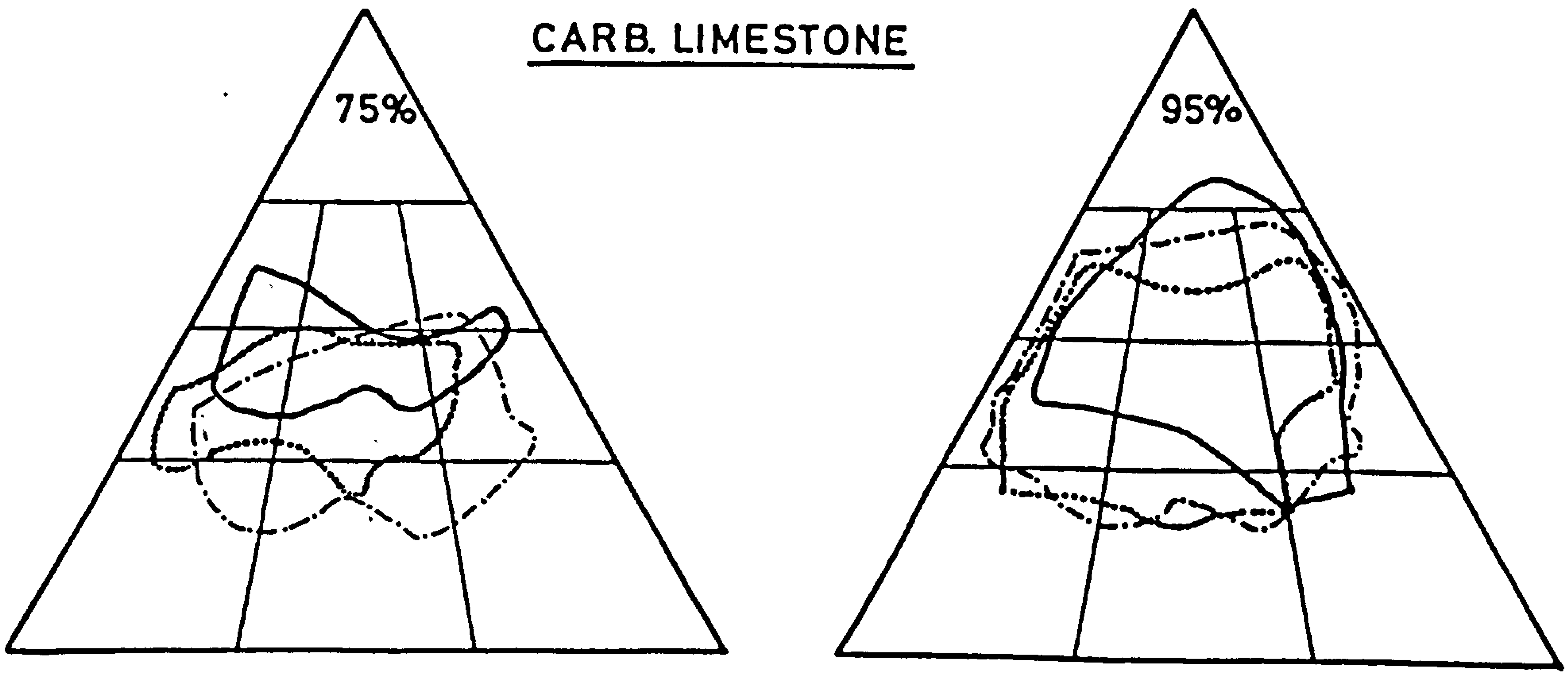
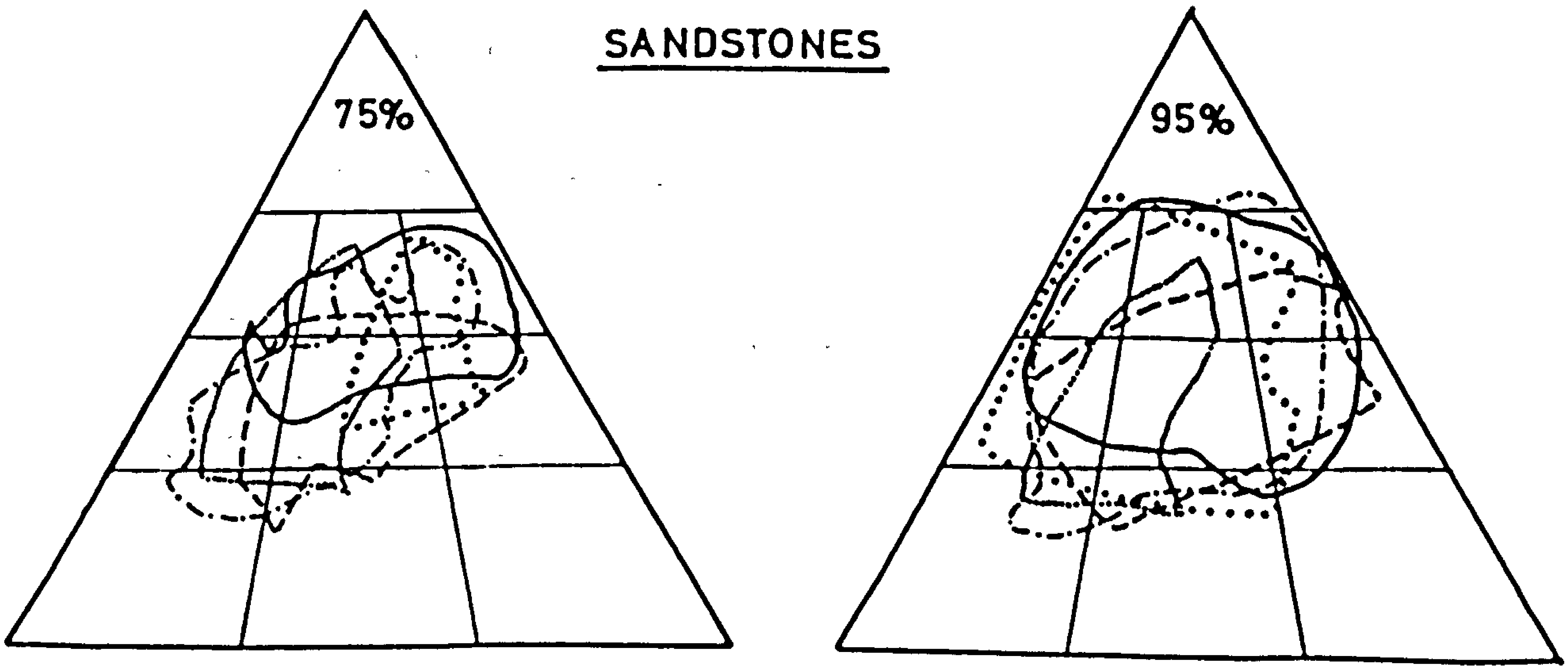
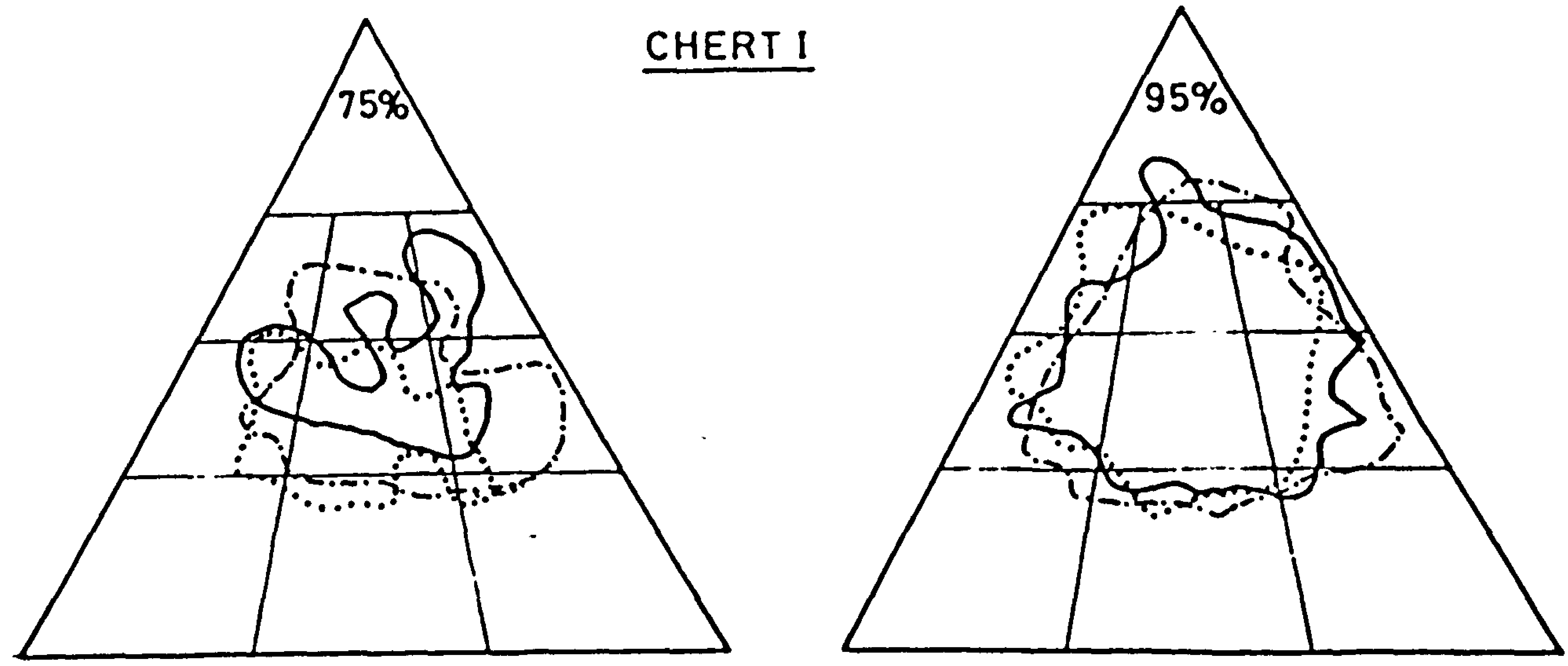


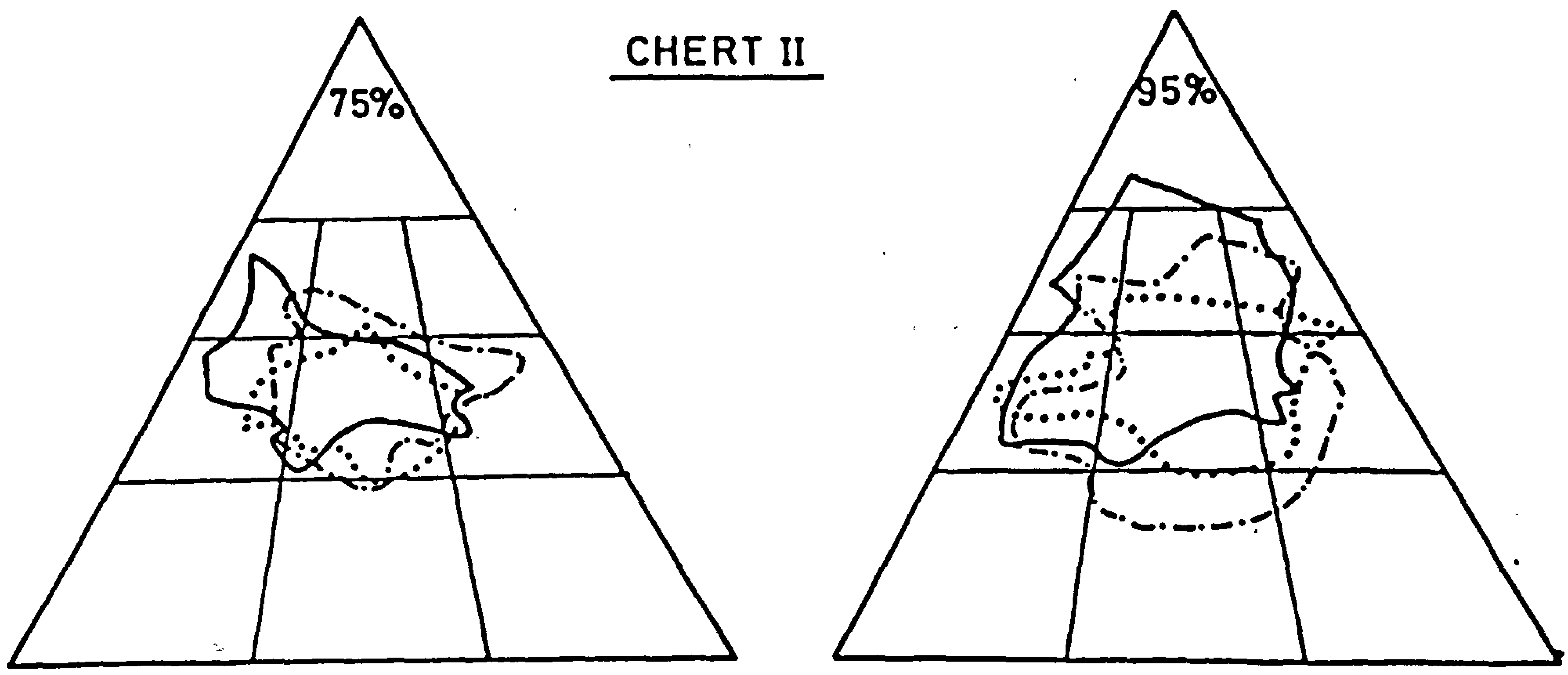
Figure 5.18 :

Triangular plots of Oblate-Prolate indices versus Maximum projection sphericities, showing distributions of 75% and 95% of pebbles









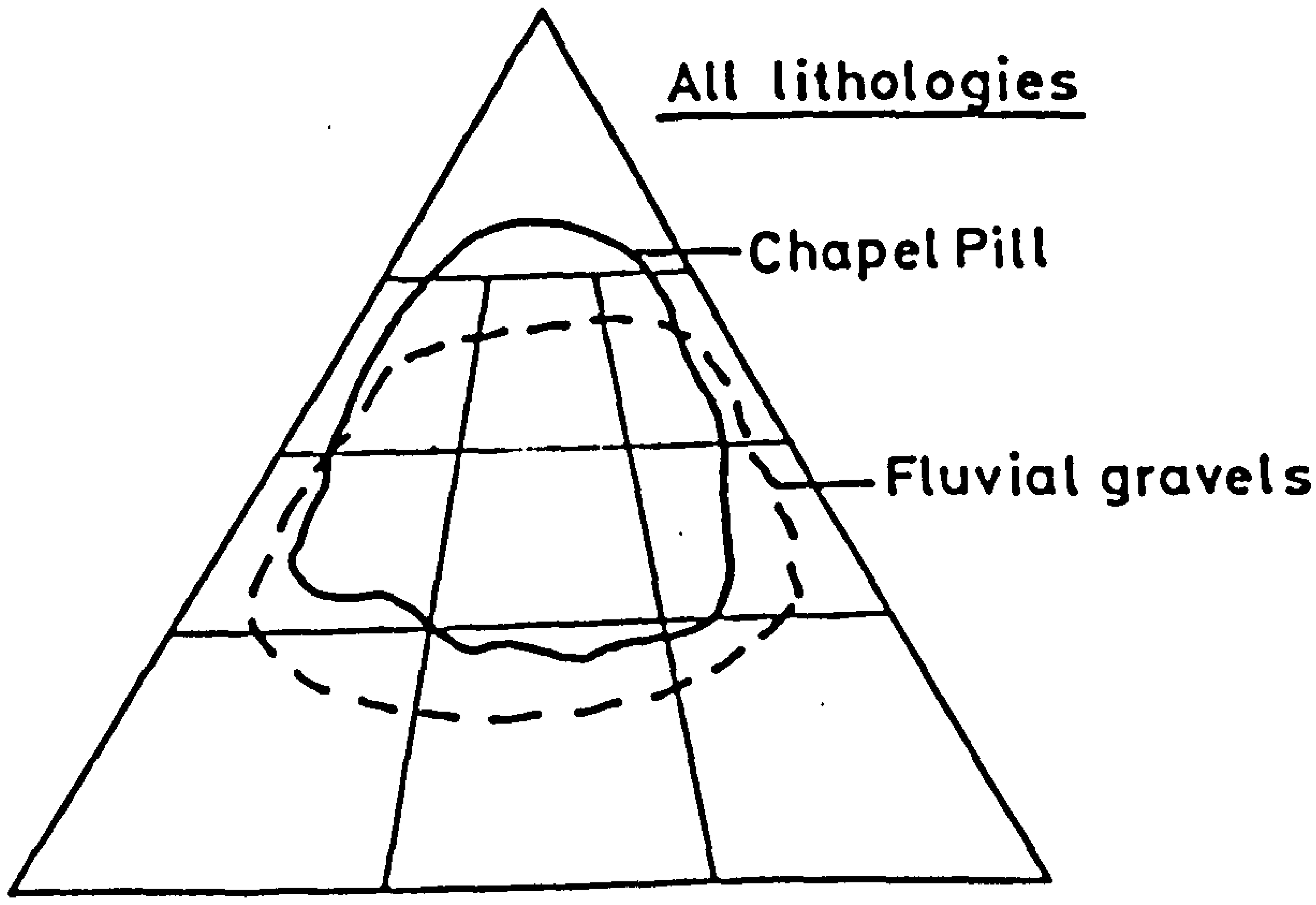


Figure 5.19 :

Triangular plots of Oblate-Prolate indices versus Maximum projection sphericities, for chert Types I and II, and summary of results from all lithologies

The OP Index/MPS triangles therefore give similar results to the Folk form triangles, with the glacial pebbles characterised by a more compact form and the fluvial/fluvioglacial gravels by a tendency towards more platy and elongate shapes.

6. Cumulative frequencies of the Elongation Index : Fig. 5.20 shows the cumulative frequencies of the percentage elongation results. This is the expression of the intermediate pebble diameter as a percentage of the longest i.e. 100% = a square or sphere, 75% = where the pebble is 1½ times as long as it is broad, and 50% = a needle shape, twice as long as it is broad.

The results of the Carboniferous Limestone and sandstone samples are again found to be largely indeterminate, with the Stidham and Chapel Pill examples giving similar ranges and distributions. The Carboniferous Limestone especially shows very few examples of needle shapes or near spherical ones, but a wide range of the "rolled" types. If the Dolomitic Conglomerate at Wraxall is considered, the glacial pebbles show the greatest range of shapes and are slightly more spherical than the fluvioglacial types, although the differences are only marginal.

The Cretaceous flints of the terrace gravels give a wide range of values while the Chapel Pill flint is more limited to those types with a % elongation of 50-80%. This is in contrast to the results of the other tests, where the Chapel Pill pebbles appeared as more spherical/compact and with a wider range of shapes. The power of this test is therefore seen to be weakened by only considering two dimensions.

The Chapel Pill and Ham Green pebbles can be distinguished from the majority of the Greensand chert Type I group by having a wider range and, as found with the Cretaceous flints from this site, a greater concentration of the rolled/bladed group. The small number of pebbles of Type I chert at Stidham cause it to have a small shape range.

The Greensand chert Type II pebbles separate best of all into their various environmental groups, as was seen with the other tests of particle morphology also. The Chapel Pill examples are as usual the most spherical,

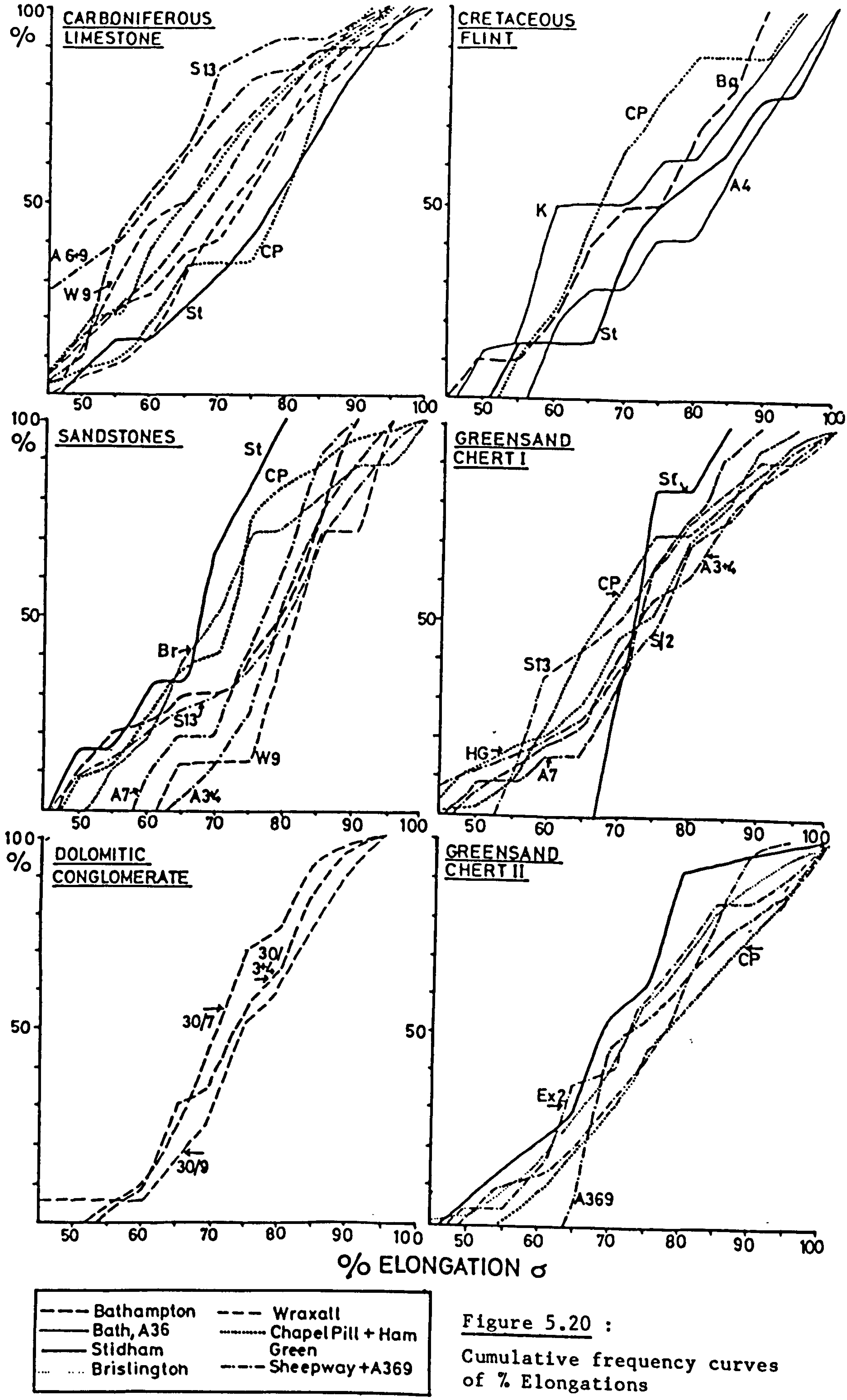


Figure 5.20 : Cumulative frequency curves of % Elongations

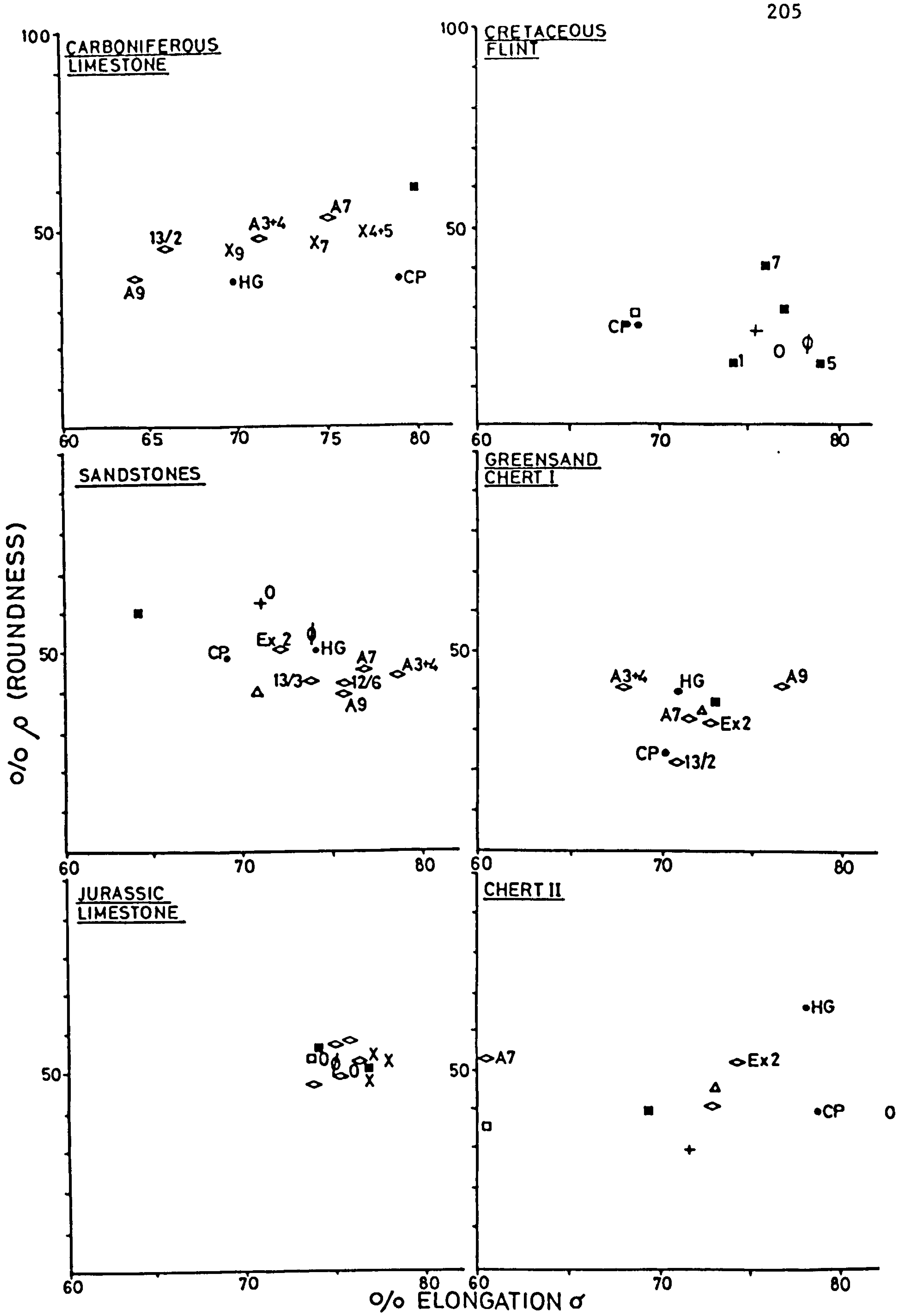


Figure 5.21 : Plots of Visual roundness versus % Elongation

with no needle shapes, while the Sheepway Exposure 2 and A369/7 pebbles give similar distribution curves. The Stidham Cherts have the widest range though, and are more dominated by the rolled/bladed shapes, 65% showing less than 75% elongation, while only 50% of the glacial examples are as elongated.

7. Visual roundness versus elongation : The final diagram, Fig. 5.21, plots the mean values of visual roundness against the mean percentage elongation. The Carboniferous Limestone illustrates a wide range of shapes, but a limited range of roundness values. This is taken to show that its solubility results in clasts quickly attaining a relatively high degree of rounding of the corners and edges, while the discontinuity geometry of a particular pebble strongly controls its overall shape. Significantly the Chapel Pill and Ham Green pebbles are least rounded, which may result from them originating as local products of frost shattering and weathering which were then collected together as glacial debris.

The Jurassic limestone results are included to emphasise how their solubility causes them to cluster around an elongation range of only 73-77%, and with a mean roundness of 40-55%, one of the highest found amongst the samples.

Roundness of the far travelled materials differs quite considerably between the various deposits, but with the only significant trend being that the glacial cherts of Type II from Ham Green, Chapel Pill, Brislington and Sheepway Exposure 2 are more rounded than the terrace cherts of Stidham, Keynsham and Sheepway.

Conclusions :

The combination of measures of pebble morphology of the Bristol Avon gravels result in the following conclusions :

1) The best lithologies for a study of particle shape are the more resistant, isotrophic and compact types, such as the flints, cherts and haematite. Limestones and sandstones tend to be either very soluble and

therefore quickly reach a relatively uniform shape, or else lithologically variable and with strong, inherent breakage/shape characteristics.

2) The glacial gravels at Chapel Pill and Brislington have a larger mean grain size, i.e. have a greater pecentage of coarser gravel than the true terrace material from Bathampton-Keynsham. They are also more poorly sorted.

3) The glacial gravels tend towards compact or elongate shapes, whereas the terrace material has more platy components. The commonest pebble shape amongst both groups however is bladed or rod-like. The results are shown by the Form triangles, the oblate-prolate Index and the maximum projection sphericities, and the percentage elongation indices.

4) The pebble sphericities of most of the gravel samples are not significantly different. The exceptions to this are the glacial samples from Chapel Pill, the A369, and Sheepway Exposure 2.

5) The soluble limestones tend to be more rounded in the terrace deposits and more angular in the glacial ones. In contrast, the resistant cherts from the tills are more rounded than those from the fluvial gravels.

COMPARISONS WITH OTHER STUDIES :

As discussed above, other workers have used morphometric data to assess the importance of pebble shapes, together with particle size and lithology, in various ancient and modern sediments. Wentworth (1936) studied the shapes of glacial cobbles from terminal moraine, but the wide range of sizes and predominance of limestone in his samples, gave results dominated by parallel sided or tabular forms. Thus the initial breakage pattern and susceptibility of the rock to abrasion overshadowed any environmental determination of shape. These factors have been shown to influence strongly the shape of limestone pebbles from the Avon samples also.

Amongst the subsidiary shapes that Wentworth differentiated, the pentagonal, "flat iron" form was the commonest, and has often been considered characteristic of glacial pebbles. Most of his sample was moderately to well rounded and over ¼ showed subparallel striations.

Flint (1971) also emphasised that the majority of clasts from glacial deposits retain those shapes inherited from their parent rock type, being bounded by joint or striation surfaces. He thought that the only way this shape pattern could be changed was by grinding or crushing by ice contact. A comparison of shapes of clasts in outwash from a till proved that any actual "glacial shapes" disappeared quickly with transport, as superficial striations were rapidly abraded and the facets rounded.

Davis (1958) made a study of the variations in lithology with size, between samples of fluvial gravel and glacial tills. He considered that the variation of lithological percentages within the larger gravel sizes was far less marked in the tills than in the stream gravel. However it is interesting that he noted a striking change in lithologies between the fine to medium gravel and coarse sands, whereas the lithologic change was small in sizes larger than 4mm (medium gravel). This situation is paralleled by the differences noted at Ham Green and the A369 between the lithologies of the finer material of the tills and those of the medium to coarse gravel. Again Davis considered that glacial outwash would rapidly develop size lithology characteristics intermediate between till and fluvial gravels, due mainly to sorting processes.

More recent studies of the Thames gravels by McGregor and Green (1978 and 1983) emphasised the need to restrict the range of particle sizes in a pebble sample and to separate the various lithologies. They also classed the pebbles from their samples into local and far travelled material, since the shapes shown by the local lithologies fluctuated considerably. A similar situation was recognised during the present work on the Avon gravel samples.

In agreement with previous workers (e.g. King and Buckley, 1968), McGregor and Green considered roundness, calculated from visual charts, to be the best measure between the different environments. In later work, however, they suggest that lithostratigraphic links/differences between deposits may be more sensitive indicators of environment than morphostratigraphic results.

Similar general conclusions can be reached concerning the lithological and morphological attributes of the Avon samples.

SUMMARY OF CHAPTER 5 :

The purpose of the sedimentary analysis undertaken during the present study and discussed above, was to produce detailed sedimentological descriptions and comparisons of the various deposits. This would then permit :

a) some suggestions concerning the environments of deposition recorded by the materials,
b) a correlation of these newly described deposits with those previously recorded in the scattered literature on the terraces.

The following facts emerged from the sedimentological analysis :

1) The field evidence and descriptions of the gravels led to a distinction being made between :

i) the typical fluvial gravels found for example at Stidham,
ii) the ill-sorted, more muddy gravels found for example at Sheepway,
iii) the glacial debris, often referred to in the past as terrace material, found for example at Chapel Pill.

2) This classification can now be further defined in terms of the grain size distributions and sorting of the materials. Three groups of fluvial gravels, two of fluvioglacial gravels, and two of glacial tills have been described above.

3) A consideration of the lithologies of the deposits supports the classification, with the fluvial gravels dominated by local Jurassic limestones, and lesser amounts of Carboniferous limestones and sandstones. The far-travelled components are typically Greensand chert and Cretaceous flint. The small amounts of these that are found in the true terraces can be accounted for by normal fluvial transportation from their source area to the south and east, with the percentage of flint gradually decreasing with distance downstream.

The far greater amounts of chert found downstream from Brislington cannot be explained in this way. These rock types are diagnostic erratics of the glacial tills known in the area, and chert in particular dominates the deposits at Brislington and Chapel Pill. The fluvioglacial gravels studied from the A369 ditch near Sheepway contain relatively large percentages of chert and flint since they have been deposited by streams draining local areas of glacial till.

4) The study of the varying pebble forms showed there to be some distinction between the shape categories developed in the fluvial gravels and those of the glacial deposits. However this distinction is not claimed to be more than a broad trend, and it was important to note the influences of material size and lithology.

CHAPTER 6

FAUNAL MATERIAL AND LOWER PALAEOLITHIC ARTEFACTS FROM THE BRISTOL AVON GRAVELS

THE FAUNAL REMAINS OF THE PLEISTOCENE :

Before listing the finds from the River Avon valley, it is useful to note some of the problems encountered on studying faunal remains from this period of British Prehistory.

The Pleistocene faunas have been divided into those predominant during glacial periods and those of interglacial climates. Several facts arise from this. Firstly, the speed with which the change between a glacial and an interglacial period is reflected in the animal population is obviously a factor of the rate, type and severity of the climatic change, with something of a lag effect more evident amongst those species that are less sensitive to their environment.

A second factor to note is that it is easy to assume that present day cold faunas found in Pleistocene contexts mean past glacial or periglacial conditions: even today there is still a glacial flora on Scottish mountain tops, whilst "tropical" animals can survive in the Northern Hemisphere zones. At the same time it is relevant that, where species are living on the limits of their tolerance zones, a slight change in climate or vegetation alone can cause great mortalities or migrations. Mammals, however, being warm blooded, are quite tolerant of a wide range of temperate conditions and have shown just how capable they are of adaptation e.g. the woolly rhinos and mammoths.

Generally a population comprising species of reindeer, musk ox, lemmings, arctic fox, woolly mammoth, etc. is considered a cold resisting fauna, whilst that including hippo, straight tusked elephant, rhinoceros etc. would be of a warmer or more temperate type, see for example Stuart (1982), Birks and Birks (1980). After these broad groups have been defined, a more detailed analysis of the environment can be gained from the evidence of pollen spores, insects, and cave deposits. These are not directly relevant to the present study since their preservation in fluvial and fluvioglacial deposits would be extremely unlikely. This is unfortunate as no backup evidence is provided to the scattered finds of bones from the river gravels.

Another limiting factor is the speed of faunal change. For example, there is evidence to suggest that during interstadials a short lived migration of warmer faunas into the formerly periglacial areas has occurred at times. Likewise the final retreat of this fauna, in the face of consistently deteriorating seasons, may actually take place well into the next glacial period.

Finally, some check has to be made as to whether the bones retrieved from a deposit are the remains of animals which were living on a gravel surface, and which died there , later to be incorporated within the terrace as it was aggraded, or whether the remains are from a different environment or period, which were eroded and transported by streams etc. to be deposited within later gravels. (Often terrestrial animals are well represented within a terrace fauna.) This situation seems to have occurred in the case of the Hanborough Terrace of the River Evenlode, Oxfordshire, where a Wolstonian Terrace has incorporated earlier interglacial remains (Briggs and Gilbertson, 1972).

The major species encountered through the Quaternary in the British Isles, during the maximum stages of the main cold and warm periods include the following (West, 1968; Sutcliffe, 1983; Stuart, 1982; Birks and Birks, 1980):-

Anglian Cold Stage : Commonly found are remains of red deer (Cervus elaphus), reindeer (Rangifer tarandus), horse (Equus), and possibly the woolly mammoths (Mammuthus primigenius) and woolly rhino (Coelodonta antiquitatis).

Hoxnian Warm Stage : The faunas here include the straight tusked elephant (Palaeoloxdon antiquus), wild boar (Sus scrofa), Fallow, Red and Roe deer, all of which are woodland types. Also found is the horse, along with cave bears, aurochs and the Great Irish Deer (found for the first time). Two extinct rhinos, Dicerorhinus kirchbergensis, and D. hemitoechus, were fairly common herbivores of the floodplains. The absence of mammoth, Bison priscus and Crocuta crocuta (hyena) is notable.

Wolstonian Cold Stage : The second major cold phase deposits include mammoth, woolly rhino, horse, reindeer, bison etc.

Ipswichian Warm Stage : This fauna is far better known than the previous periods, and can be divided into four zones. Equus ferus is found from the start of Ipswichian Zone I (Ip.I) and is associated with open woodlands or grasslands. The classic Ipswichian fauna (the "hippopotamus" fauna) of zone IIb includes Palaeoloxodon antiquus, Crocuta crocuta (hyena), Dicerorhinus hemitoechus, Hippopotamus amphibius and Dama dama (fallow deer), though Equus ferus is now absent. The environment suggested is regional mixed oak forest with local herbaceous vegetation. In zone III the reappearance of the mammoth and horse may coincide with the opening out of the forest, while hippo and Dama disappear. Zone IV continues the climatic deterioration with open coniferous woodland dominating and the appearance of arctic-boreal species e.g. the woolly rhino and musk ox, while Palaeoloxidon antiquus has disappeared. The continued presence of Bos primigenius however suggests considerable summer warmth in a continental climate, with great seasonal variations.

Devensian : The Early faunas are dominated by Bison priscus and Rangifer, but Equus ferus and Mammuthus primigenius are rare. By the Mid Devensian Bison priscus has become rarer while Equus and Mammoth are abundant. In the Late period Bison priscus became extinct and by the end of the late period (after 15000BP) woolly mammoths and rhinos were unknown. Musk oxen appear to have been very sparse, found during the coldest periods only.

FAUNAL REMAINS FROM THE GRAVELS OF THE RIVER AVON :

The majority of the remains reported in the literature are limited to sites above Saltford. Many bones were removed and studied in the 1800s so that often an identification alone is all that is known, with little or no reference to their position within the gravels etc. They then became dispersed through several collections and little now remains for study. A series of boxes of mixed, and largely unlabelled, examples of mammoth teeth found in the Bath Geological Museum is the only trace of the many bones recovered around Bath in the last century. Since then no major finds have come to light, due mainly to the lack of excavations within the gravels, much of which were wholly removed. The trenches dug at Stidham Farm (see Chapter 4) revealed no faunal remains throughout their 120m length, reinforcing the view that most of the bones were concentrated upstream of this site.

The finds recorded in the literature are set out in a tabular form in Fig. 6.1. They are separated into a) cold resisting types, b) more temperate species, and c) those which can adapt to tolerate both regimes (non-specific). As can be seen, the commonest bone types are teeth and small, compact-shaped bones such as the astragalus and calcaneum (heel bone), suggesting that some transportation and sorting occurred prior to deposition within the gravels.

Fig. 6.2a shows the occurrence of each species throughout the Middle and Upper Pleistocene in the British Isles, adapted from A.J. Stuart (1982). Fig. 2.6b uses this information to plot the earliest possible date at which the fauna from each site could have become collected together i.e. the date of the occurrence of the latest addition to the fauna. For example, at Larkhall the woolly rhino and mammoth (dating from the start of the Wolstonian), postdate all the other species (which were present in Britain from at least the Hoxnian or earlier).

This method presumes several facts :

1) That the time ranges given for the various species are roughly correct;
2) that all the bones from any one site include all possible species from that site i.e. a later species which gives a true terminus post quem for the deposit has not been omitted.

Figure 6.1 : Quaternary faunal remains from gravel deposits of the Lower Bristol Avon

SITE	Cold Resisting fauna	Non-specific	Warm/Temperate fauna
Freshford	Rangifer tarandus (Leg bone) Ovibus moschatus (1 male, 2 female head) Coelodonta antiquatatis (tooth) Mammuthus primigenius (tusk and molars)	Bison priscus	Sus scrofa (canines)
Limpley Stoke	Mammuthus primigenius (1 ultimate lower molar)		
Bathampton	Mammuthus primigenius (1 ultimate lower molar)		
Larkhall	Rangifer tarandus Mammuthus primigenius (3rd lower molar) Coelodonta antiquitatis Coelodonta antiquatatis	Ursus sp. Equus ferus	Sus scrofa Bos primigenius Palaeoloxodon antiquus (molars)
Victoria Pit	Coelodonta antiquatatis (molars) Mammuthus primigenius (molar, bones & tusk)	Equus ferus (teeth and metatarsals)	Bos primigenius (molar) Palaeoloxodon antiquus (molar)
Lambridge	Mammuthus primigenius (7 foot long tusk) Coelodonta antiquitatis		
Boyce Hill	Mammuthus primigenius Coelodonta antiquitatis		
Wells Road	Mammuthus primigenius (2 ult. lower molars)		
Westgate St.			Sus scrofa
Loxbrook	Rangifer tarandus Mammuthus primigenius Coelodonta antiquitatis	Panthera leo	Bos primigenius Megaceros giganteus
Lyncombe & Widcombe Cemy.	Mammuthus primigenius		
Morefield	Rangifer tarandus (horn) Mammuthus primigenius Coelodonta antiquitatis		Bos primigenius (molar and astragalus) Cervus elaphus (horn)
Twerton	Mammuthus primigenius (molars, tusk, incisors, tibia, calcaneum)	Bison priscus	Megaceros giganteus
Newton St. Loe	Mammuthus primigenius		
Saltford	Mammuthus primigenius (penult. lower molar)		
Cumberland Basin	Coelodonta antiquitatis	Equus ferus	Cervus elaphus

Figure 6.2a : Occurrence of species throughout the Middle-Upper Pleistocene of the British Isles (after Stuart, 1982)

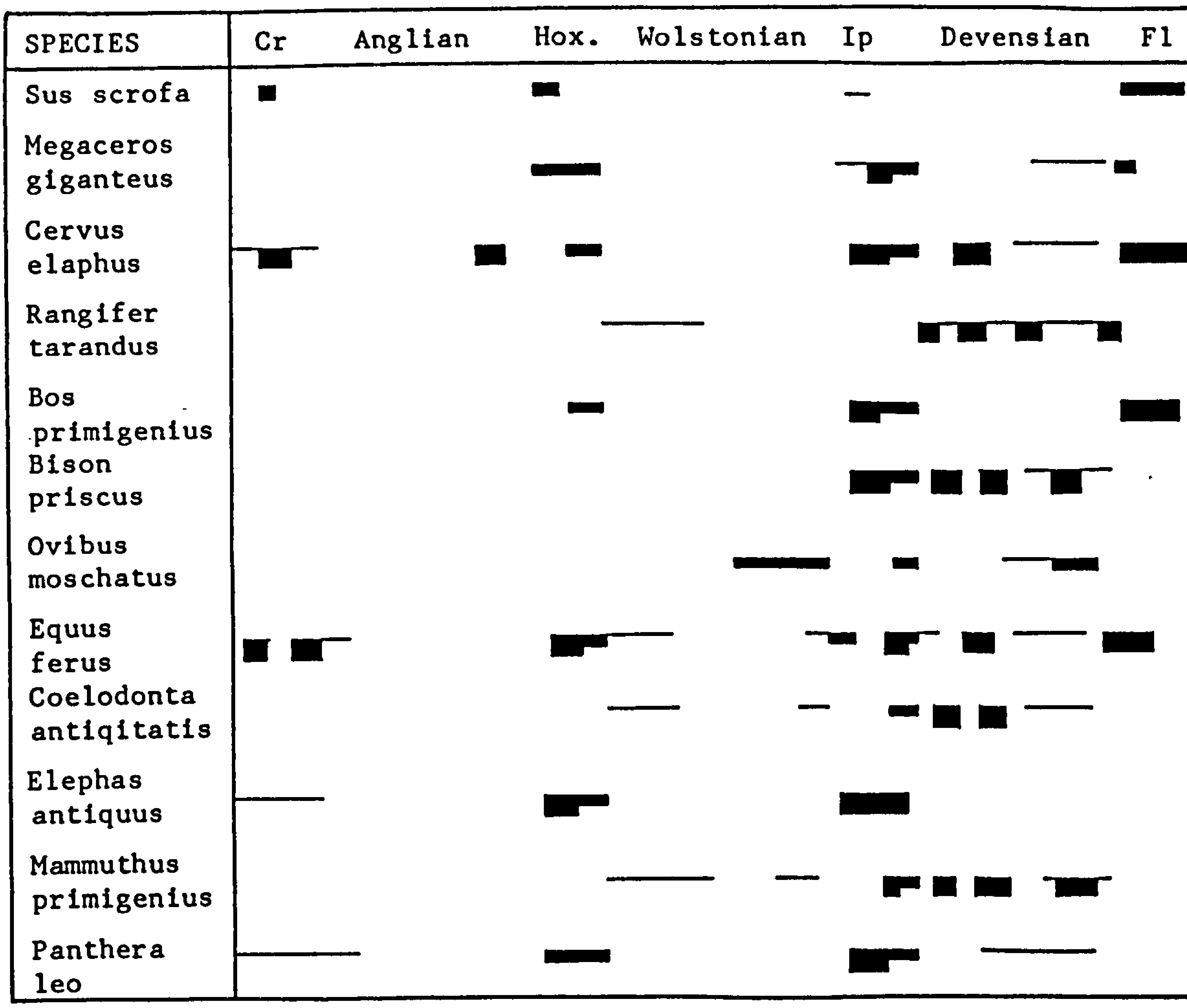


Figure 6.2b : Earliest possible dates of occurrence of faunas from each of the Bath findspots

SITE	Cr	Anglian	Hox.	Wolstonian	Ip	Devensian	Fl
Freshford					X		
Larkhall				X			
Lambridge				X			
Boyce Hill				X			
Loxbrook				X			
Lyncombe & Widcombe Cy.				(X)			
Victoria Pit				X			
Morefield Cutting				X			
Twerton					X		
Newton St. Loe				(X)			
Saltford				(X)			
Cumberland Basin				(X)			

3) that all the bones recorded from one site are from one layer or gravel series.

The finds recorded in the literature will now be discussed :

At Freshford, south of the Limpley Stoke Gorge, Moore (1869) lists the finds as consisting of the tusk and teeth of a mammoth, the tooth of a woolly rhino and two heads of musk oxen, one male and one female. These were all found in a small basinal hollow southeast of the village. Dawkins (1866) also mentions these finds, together with remains of elephant and horse from around Freshford Station, in unsorted gravel made up of both angular and waterworn pebbles.

Dawkins and Reynolds (1872-1939) give a better description of the site. They quote musk ox, mammoth, bison, horse and reindeer being found in a lenticular mass of gravel of waterworn pebbles of Carboniferous Limestone, chert, flint, oolitic limestone, hornstone (black chert) quartzite and Old Red Sandstone. The gravel had some larger blocks at the base and the whole bed was very confused. They suggested it could only have been deposited by an "ice burdened river under severe climatic conditions".

Above the gravels (which reached 2.4m thick) was 1.5m of "clay with flints", 0.3m of oolite hillwash, and 1.2m of red loam. These suggest periglacial and solifluction deposits as seen at Bathampton. The whole sequence lies against a cliff feature of Inferior Oolite with the gravels between 9 to 14m above the Avon.

In the Bath Museum, one ultimate lower molar of a mammoth is preserved, though only labelled as "from Limpley Stoke". There is also a similar tooth from Bathampton.

A number of finds were recorded within the City of Bath itself (see Fig. 6.3). Lonsdale (1832) gives the first mention of the pit at Larkhall producing bones of Elephas, Sus, Coelodonta, Equus, Bos and Ursus. Moore (1869) describes the stratigraphy of the pit as consisting of 2.4m of gravel over the Lias Clay. Above this was up to 2.4m of laminated and mottled brown and blue clays and a further 4.5m of gravel from the Oolite and Upper Lias, presumably hillwash. He noted that most of the faunal

Figure 6.3 : Areas of gravel deposits and sites of finds of faunal remains, Bath

remains were from the lower gravel, while from the marls above were recovered many shells of Pupa marginata and Succinea oblonga, plus some Helix spp.

At Lambridge, Winwood (1886) noted remains of woolly rhino and a 7 foot long mammoth tusk. This had been described by Warner (1801) as being found in 1799, in a complete state but so decomposed that it could not be removed.

Moore (1869) noted more mammoth teeth from the Lyncombe and Widcombe Cemeteries, while preserved in the Bath Geological Museum are two ultimate lower molars of a mammoth, from the Wells Road.

At Twerton, former areas of gravel have now been worked out, but in three pits, alongside the railway line, many faunal remains were found in the past. The pits were at Claude Avenue (the Morefield Cutting), the Victoria Pit, and the Bellott's Road Pit.

Winwood (1874), in describing the Morefield Cutting, noted the remains of Mammuthus, Bos and Cervus from a band of yellow sandy clay within the gravels. As mentioned by many workers, large blocks of Inferior Oolite were found at the base of the formation. The lowest level of sands, a few inches above the bedrock, and below the mammalian bed, gave shells of Bythinia, Pisidium amnicum and Zonites. Oriel (1903) quotes Winwood and adds that the gravels are here at 152 ft (46m O.D.). He also mentions that many of the fossils were found resting on the top of the Lias, so that one side is tinted blue from the clay and the other yellow from the gravels.

The second site, the Victoria Pit, lay at about the same height,and again the bones were resting on the Lias Clay. Amongst the finds was a molar fragment of Palaeoloxodon antiquus. Also preserved was a mammoth tusk, with an outer curve length of 420mm and a maximum circumference of 270mm. This is probably the tusk still preserved in the Bath Ref. Lib. Museum. It was mentioned by Winwood as resting in ferruginous and black gravel bands immediately over the level of large boulders and the Lias Clay.

The third excavation was at Bellott's Pit at c. 88 ft (27 m O.D.) and here Oriel (1903) states that the bones were mixed with the gravel rather than lying at their base. Therefore at the three Twerton sites there seems to have been one level of remains immediately above the Lias Clay, and another in a sandy clay level within the actual gravels. It seems likely that this pit (termed simply "Twerton" by Winwood) is the source of the mammoth molars, tusk, incisors, tibia and calcaneum he listed in 1886.

Another site, at Westgate Street, where a cellar was being excavated, produced bones of Sus scrofa.

Moving downstream and to the opposite side of the river from Twerton, the Locksbrook Cemetery and gravel pit yielded remains of a variety of species i.e. Rangifer, Mammuthus, Coelodonta, Panthera, Bos, and Megaceros. There is some confusion over these in the literature as Dawkins (1866) lists these as found by Winwood. Winwood's own paper of 1886 (including a table of mammals found) does not include them however.

Winwood (1897), on the Rhaetic exposure at Boyce Hill, includes details of several sections through the superficial beds. Most notably, one of these sections gives large blocks of grit resting on the White Lias, below gravel and red-yellow sandy marl with fine gravel. This whole deposit was c. 1.5m thick, while lying over it was firstly 0.4m of mottled grey and red marl and 0.5m of red-brown clay with stones and subangular Lower Lias blocks. The gravel is recorded as at 37 ft above the river (or c. 26m O.D.) and from within a yellow clay band parts of a mammoth's tusk and woolly rhinoceros tooth were found.

Leaving the City, more remains such as Mammuthus and Equus are recorded by Owen (1846), Dawkins (1866) and Moore (1869) from Newton St. Loe. At Saltford, Winwood and Moore recorded mammoth teeth and one penultimate lower molar is still preserved in the Bath museum.

This concludes the literary evidence of faunal remains from the Bath area.

In considering the implications of these finds several points emerge :

1) There are two heights at which the mammaliferous Bath gravels occur -
   a) at c. 23-30m O.D. eg. at Freshford, Larkhall, Lambridge, Locksbrook, Boyce Hill and possibly Newton St. Loe;
   b) at c. 46m O.D. eg. at Morefield Cutting and the Victoria Pit.

2) The gravels described are basically very similar, with a basal level of large boulders over the Lias Clay bedrock. Over these lies the main gravel, often with intercalated sandy and clayey bands. Above these may be a layer of finer material such as muds, gravelly muds, or hill-wash and solifluction deposits. The overall stratigraphy is very similar to that recorded at Bathampton (see Chap. 4).

3) The faunal remains are found either at the gravel base, near the Lias Clay contact, or within the sandy muddy lenses, or, in some cases, simply mixed in amongst the gravel.

4) Except at Lambridge and Boyce Hill (where the faunal remains are solely of a cold resisting type), the major sites have yielded a mixed fauna including also the more temperate types and those species tolerant of a wide range of conditions.

5) If the conclusions drawn in Fig. 6.2b are correct, i.e. they give a terminus post quem for the gravel deposition, then all the deposits date to the start of the Wolstonian at the earliest. This date would fit with the depositional setting for these gravels.

The Bath gravels represent episodes of high energy flow transporting a mixed load of material over relatively large distances (pebbles included are of Carboniferous Limestone, ORS and flint and chert). Included with them are a variety of species from Bos, Palaeoloxodon, Cervus and Megaceros to Mammuthus and Coelodonta.

It is suggested that the gravels were deposited sometime during a middle to late glacial period (possibly the Wolstonian).

Material made available by frost shattering and weathering, plus the products of solifluction, stream bank collapse etc. caused by thawing, was transported by meltwaters. This flow was turbulent and intermittent, sorting the materials to some extent, but generally carrying a mixture of material. The large amount of sediment and the intermittent flow caused the aggradation of sand and gravel terraces.

Mixed with these deposits are the faunal remains. These accumulated when a variety of species, drawn to the riverside to drink, graze or hunt, died there and their bones became incorporated into the cycle of erosion, transport and deposition. Animals which date to the early cold phase include the last of the temperate faunas, and those species which lived in the increasingly open woods and grasslands as the climate deteriorated. The cold fauna of the main glacial period, typified by woolly mammoth and rhino, are more predominant in most of the deposits.

THE FINDS OF ARTEFACTS FROM THE BRISTOL AVON GRAVELS

BACKGROUND :

Compared with the European mainland, useful evidence of Lower and Middle Palaeolithic Man is scarce in Britain. Although a large number of stone tools survive, little factual information can be derived from them, since the vast majority have either not been found in situ, or were not recorded in sufficient detail. The use of stone tools alone as the key to man's cultural activity over a period of nearly 200,000 years is a somewhat dubious one. However, they are often the only evidence available and some use can be made of them, given that there are many drawbacks.

Most Lower and Middle Palaeolithic sites in Britain are of the open type, and near either a river or a lake. At such locations, man could draw on the resources of the water, rocks, vegetation and animals, but whatever traces of his activities were left became rather vulnerable to the forces of weathering, erosion and transport, in this potentially high energy environment. It is common for stream gravel deposits to contain worn artefacts gathered from a number of sources. Even the most famous site of Swanscombe, which is often used as a basis for the Lower Palaeolithic succession, reveals a stratigraphy which includes derived tools (Evans, 1975; Wymer, 1968, 1976). A series of very worn tools spread throughout a gravel has very little value especially as the time range of those that can be assigned a date may span a very long period. However, one specific tool found within a well defined deposit can be just as important as a good zonal fossil is to the geologist.

Although artefacts have a good dating potential, in practice their "imperishability" means that they can survive through several redeposition sequences, whilst losing their freshness, associations and context in this process. How true this is in the case of the River Avon deposits will now be seen.

THE ARTEFACTS :

INTRODUCTION :

Other than short references to finds in papers by Davies and Fry (1929), Palmer (1931), and Fry (1956), where established ideas are quoted, the only papers on this subject are Lacaille's work of 1954 and Roe's of 1974, with Roe (1968) also listing findspots and tool numbers.

Sites with evidence of man's hunting and industrial activity are few, and if it had not been for the large numbers of finds at Shirehampton and Chapel Pill, they would not be worthy of much more than the scant attention they have been given in the literature.

The various tools have been stored in the Bristol City Museum, the University of Bristol Spelaeological Museum and the National Museum of Wales, in Cardiff. However, on attempting to start a study of these, it was found that many had been destroyed during World War II air raids on Bristol. Thus some of the best examples of tools are known only from drawings and descriptions in the papers of Davies and Fry, and Palmer.

Another result of the chaos caused by the Bristol Blitz was that the tools were hurriedly gathered together into boxes, often with a resultant loss of labels, and stored for the duration. Since the original labelling system of findspots had never been satisfactory in the first place, the problem of sorting out the tools is now nearly impossible. Much material in the collections was never "worked" stone in the first instance, the manufactured tools are generally of a very basic standard of craftmanship, and provenance is often limited to an area, e.g. "Kelston", "Brislington".

The present study was limited to a summary of all available information and is contained here in the form of a simple catalogue of the finds, reproducing all the information in one source. This has been assembled from the various papers, checking of some of the specimens and from Roe's card index of the tools. This formed the starting point of the study and the present author gratefully acknowledges permission to use it.

The finds will now be described in a list form, followed by a discussion of their type, manufacture, containing deposit and possible date. The full catalogue is contained in Appendix III.

RECORDED FINDS (Figs. 6.4, 6.5, 6.6)

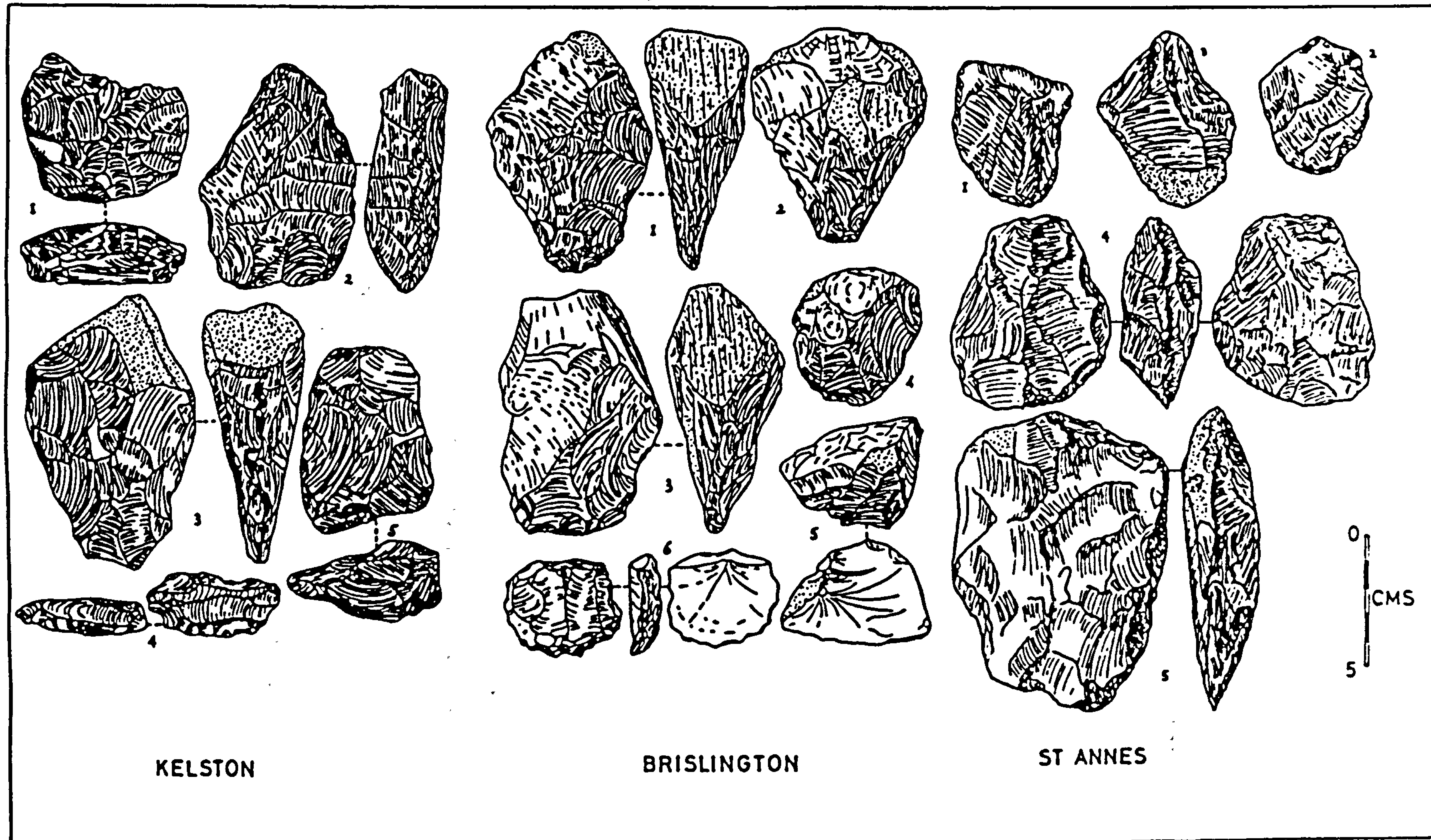
Working downstream, the first site is at Kelston, where 12 Greensand chert tools were found in 1930 (Fry, 1956). All had a light ochreous patina and only one was abraded. Fry described the area as having a scatter of surface gravel of Greensand chert, flint, and quartzite, concentrated around 46m O.D. This consisted of decalcified gravel to the southwest of the church, whereas around 700 yards northwest of the church was some "unaltered river gravel". The artefacts were all from a large level field 450-500 yards west southwest of the church (ST 694666). The decalcified material is presumably the Head deposit marked on the British Geological Survey map, and it seems likely that this was used as a source of raw material for tool manufacturing, rather than the tools being made elsewhere and deposited with the "unaltered river gravel". More recent evidence of this "terrace deposit" has already been discussed in Chapter 2.

No tools have been reported from the large areas of gravels known and excavated at Stidham and Avon Farms, Bitton and Keynsham, and indeed none were found during the present study.

The next finds recorded, downstream of Kelston, are from Brislington, where 20 were picked up in 1930, northeast of Brislington House, on the plateau above the River Avon around 46m O.D. (ST 633704). These were also of Greensand chert, with a dense ochreous patina and no noticeable abrasion. 8 tools had been found in St. Anne's in 1926, again all of chert and unabraded, on top of a thin scatter of surface gravel around 18 to 43m O.D. (ST 623725).

Fry considered all these tools to be of Acheulian date, and since they are similar to, and from the same height as, those from Shirehampton and Chapel Pill, he dates them to the Mid-Acheulian of the Hoxnian Interglacial. This date had been proposed by Lacaille two years earlier. The problem is that the Acheulian spanned from the Hoxnian to the Ispwichian Interglacial period and the Mid-Acheulian itself can be placed from Hoxnian III to Mid-Wolstonian on the basis of the Swanscombe correlations.

Figure 6.4 : Lower Palaeolithic artefacts from Kelston, Brislington and St. Annes, Lower Bristol Avon (descriptions overleaf)



Artefacts illustrated on Figure 6.4 :

Kelston : (Fry, 1956)

1. Chert disc with broken edge.
2. Small, square ended, coarse, irregular handaxe with a tapering butt.
3. Triangulate handaxe with a thick trimmed butt.
4. Small flake, retouched?, with a damaged platform.
5. Wedge-shaped handaxe.

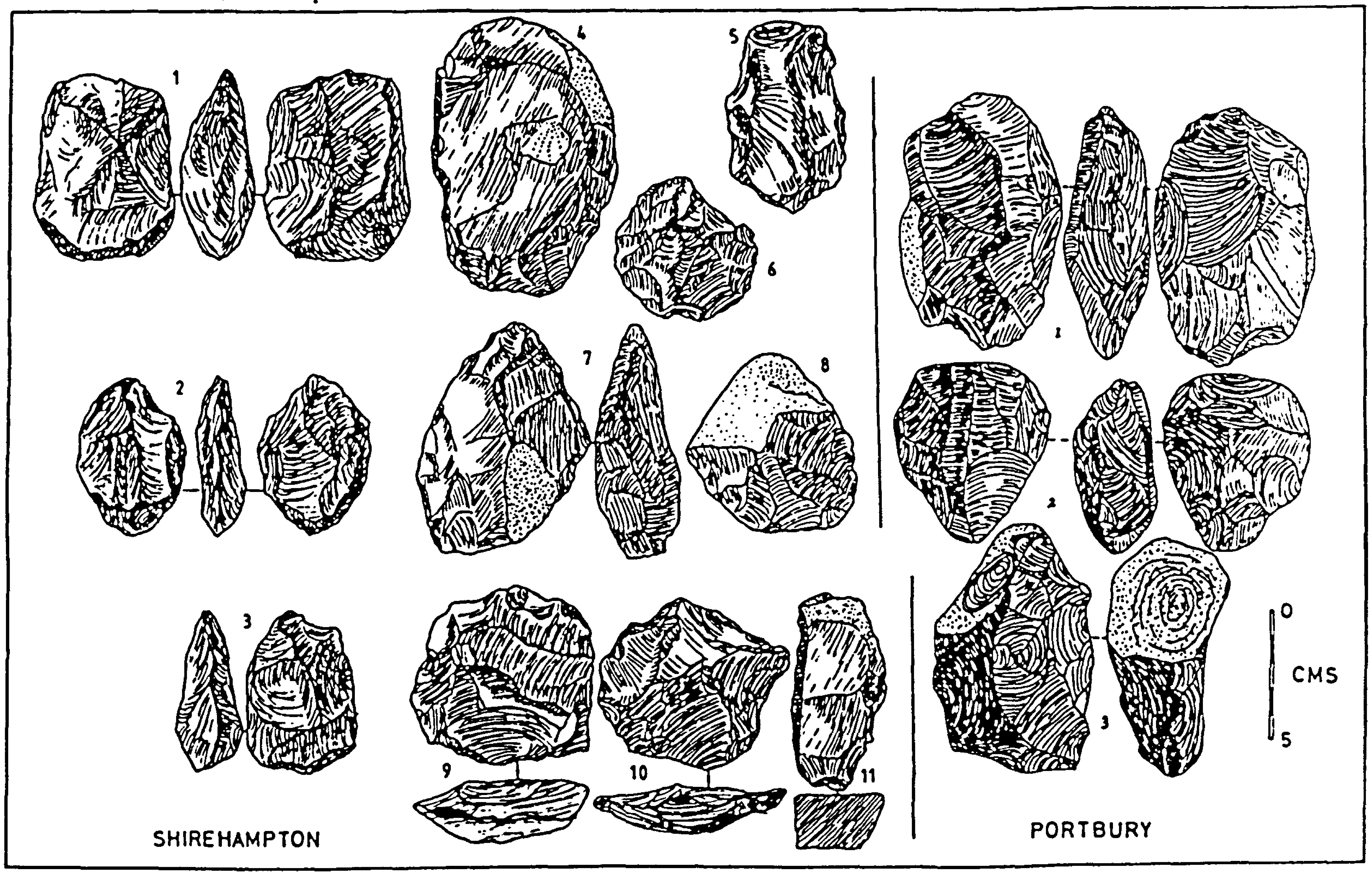
Brislington : (Fry, 1956)

1. Triangulate handaxe with a thick, angular, partly trimmed butt.
2. Triangulate pointed handaxe on a chert pebble butt.
3. Square ended handaxe with a heavy, untrimmed butt.
4. Small chopping tool.
5. Rolled, chert flake with a plane platform and steep retouche.
6. Small, narrow flake tool with a prepared striking platform.

St. Anne's : (Fry, 1956)

1. Triangular handaxe with an ochreous patina, from a height of c. 38m O.D.
2. Small worked flake, height 38m O.D.
3. Pointed tool with an untrimmed butt, height 38m O.D.
4. Small, thick handaxe, with grey patina and iron staining.
5. Acheulian handaxe with plano-convex section, from a height of c. 30m O.D.

Figure 6.5 : Lower Palaeolithic artefacts from Shirehampton and Portbury (descriptions overleaf)



Artefacts illustrated on Figure 6.5 :

Shirehampton : Nos. 1-3, Lacaille (1954)

1. Small, square-ended chert handaxe, tranchet finish on one side, moderately rolled, from Grove Leaze, 29m O.D.
2. Small, flattish, finely flaked chert tool, with pronounced dulling of all edges, 24m O.D.
3. Very small, rough, blunt chert handaxe, with pebble butt and slightly rolled, from Station Road, 26m O.D.

4. Slightly rolled handaxe, surface find from allotment, near Shirehampton Cemetery.
5. Sidescraper.
6. Small disc, broken in manufacture.
7. Broken half of an almond shaped, coup de poing.
8. Small chopper with pebble butt.
9. Levallois flake.
10. Levallois flake.
11. Side scraper.

(Nos. 4-7, 9, 11, all surface finds from around 30m O.D. [Davies and Fry, 1929])

Portbury : (Fry, 1956)

1. Coarsely chipped square handaxe with remains of cortex in parts and a dense slate grey patina.
2. Much abraded early Chellean / Abbevillian? rostrate handaxe with an ochreous brown patina.
3. Coarsely chipped, square-edged cleaver with a dense greenish brown patina.

The other minor site is at Portbury where Roe (1968) reports one possibly worked stone from the Portbury Flats (exact location unknown) and another 6 tools from the land at Sheephouse Farm (he terms it Sheepway Farm), (ST 492762 and ST 494764). They were found in 1931 and most were destroyed in World War II, as were those from Brislington and St. Anne's. They include a much abraded rostrate handaxe, which may date to the Abbevillian period before the Acheulian (Anglian to early Hoxnian). It seemed likely to previous authors that this was a derived tool, because of its worn state. The only tool from Portbury still preserved in the University of Bristol Spelaeological Museum is an extremely rolled chert flake.

The main group of finds is from Chapel Pill and Shirehampton (Fig. 6.7). Roe records a total of 450 Lower Palaeolithic tools from these sites (170 handaxes, 46 flake tools, the rest waste). This includes four Levallois cores and one Levallois flake, plus one or two Abbevillian tools, leaving the vast majority of Acheulian date.

On the south bank of the river, one tool was found near Ham Green Farm, and two other bifacials have been excavated on the Medieval pottery kiln site, but nearly 400 have been found over the years on the nearby lands of Chapel Pill Farm, and along the railway cutting around Ham Green Halt, to the south of the Farm. Although the vast majority are very weathered, a few are unmarked (discussed by Lacaille, 1954). He makes a distinction between the amount of transport and therefore abrasion a tool has undergone and the degree of weathering and thus patination it has suffered. He also notes that the high glaze of the surface of some "records the prolonged action of water and sand".

Across the river at Shirehampton, the tools seem less worn which forms an important distinction between the two sites and deposits (Brown, 1957). Here, for example, were found the three tools illustrated in Lacaille (1954) and reproduced in Fig. 6.5. The findspots are noted on Fig. 6.7 and are known only from R. Hughes notebooks. Some 14 or so artefacts have exact locations and deposit heights but again any more stratigraphic information is missing. The detailed sections recorded by Davies and Fry (1928) from Shirehampton Cemetery and ApSimon and Boon (1960) from the High Street, Shirehampton, are the only information on the deposits

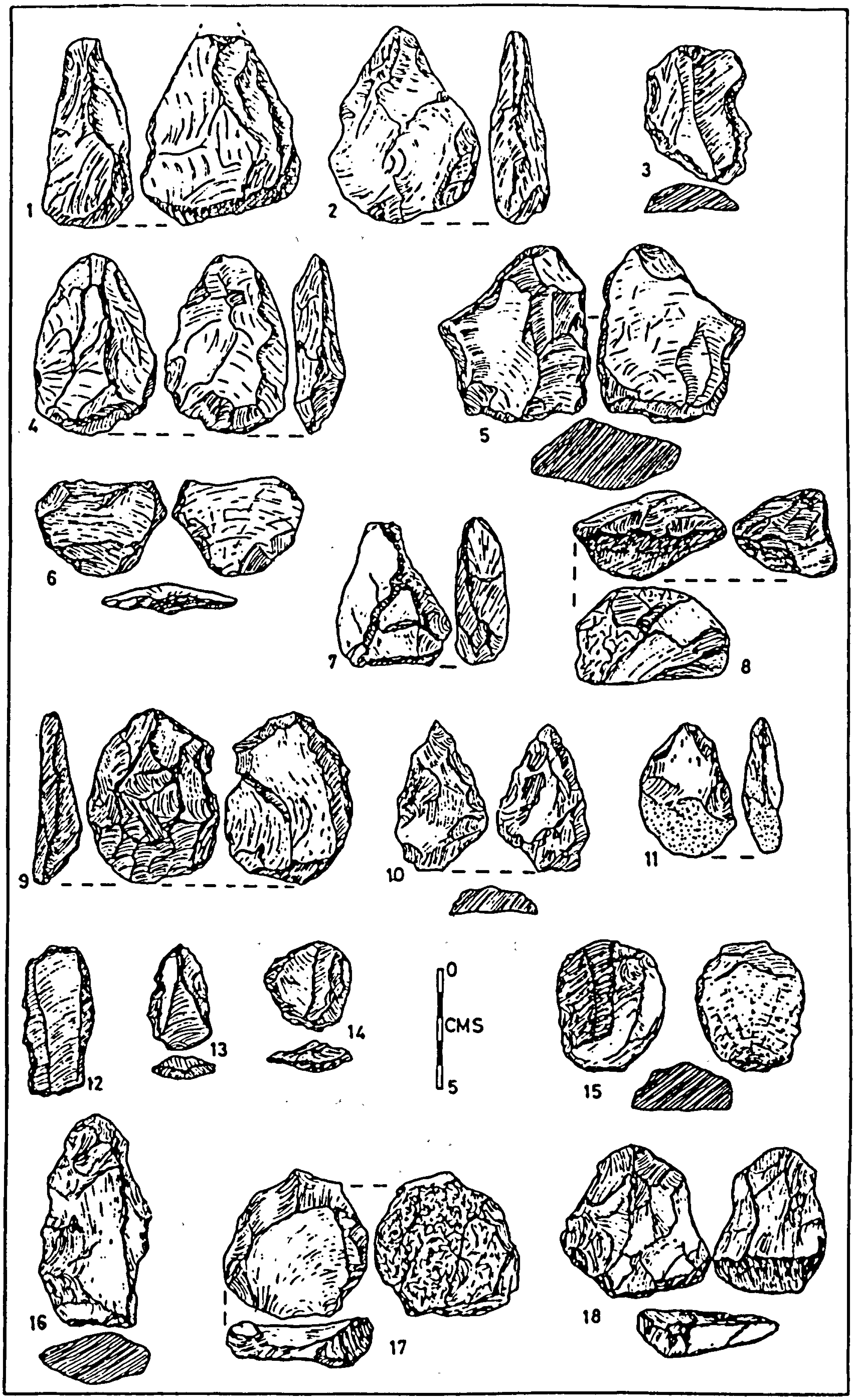


Figure 6.6 : Lower Palaeolithic artefacts from Chapel Pill (descriptions overleaf)

Artefacts illustrated on Figure 6.6 :

(NB except where stated all finds are from 30m O.D.)

1. Small triangular handaxe of brown sandstone (73.5 x 64 x 34 mm) with tip broken.
2. Triangular honey chert pebble handaxe with traces of smoothing and a twisted cutting edge on one side (76 x 59.5 x 25mm).
3. Brown chert flake tool with high glaze and retouched scraper edges (58 x 44 x 12mm).
4. Ovate, petaloid handaxe, slightly blunted, and of grey banded sandstone (72.5 x 49 x 18mm).
5. Heavy sidescraper of dark grey-green flint, patinated ochre, with some iron staining, heavily damaged edges and a prominent bulb of percussion. Acheulian/Clactonian mixture (70.5 x 58 x 23mm).
6. Flint flake, heavily patinated, with part of crust of prepared core remaining, and truncated, narrow facets on a thin butt. Levallois (40 x 67 x 10mm).
7. Small worn and weathered, triangular handaxe of chert, with a twisted cutting edge (61 x 53 x 20mm).
8. "Tea cosy" type chert core tool (poor specimen of an uncommon type) 24m O.D. (64 x 40 x 37mm).
9. Ovate flint flake tool, with twisted cutting edge due to natural contours, heavily patinated and stained ochreous. Well developed Acheulian (73.5 x 53 x 12.5mm).
10. Sharply pointed bifacially trimmed, flint flake of advanced Acheulian. Heavily patinated and light yellow stained (62.5 x 38 x 12.3mm).
11. Simple small ovate pebble handaxe of very weathered and worn chert. Surface find from 15m O.D. (59 x 43 x 17.5mm).
12. Dull beige grey flint, parallel-sided, blade from a well-prepared core. Heavily patinated and very worn and abraded (64 x 29 x 11.5mm).
13. Light beige, heavily patinated flint, leafshaped blade (47 x 28 x 8mm).
14. Patinated and ochreous stained, very worn flint, Acheulo-Levallois scraper, from 0.35m down in "head" material, at 30m O.D. (37 x 37.5 x 14mm).
15. Patinated and light ochreous stained chert flake (Abbeville/Early Clactonian) (72.5 x 44 x 24mm).
16. Very patinated, light yellow, pick and double side scraper, rudely flaked from tabular flint (66 x 29 x 20mm).

17. Patinated and yellow Levallois core in corticated chert (63.5 x 62.5 x 20mm).
18. Heavily patinated, yellow-cream Levallois core, made into a triangular handaxe by fine overall flaking (66 x 61 x 17.5mm).

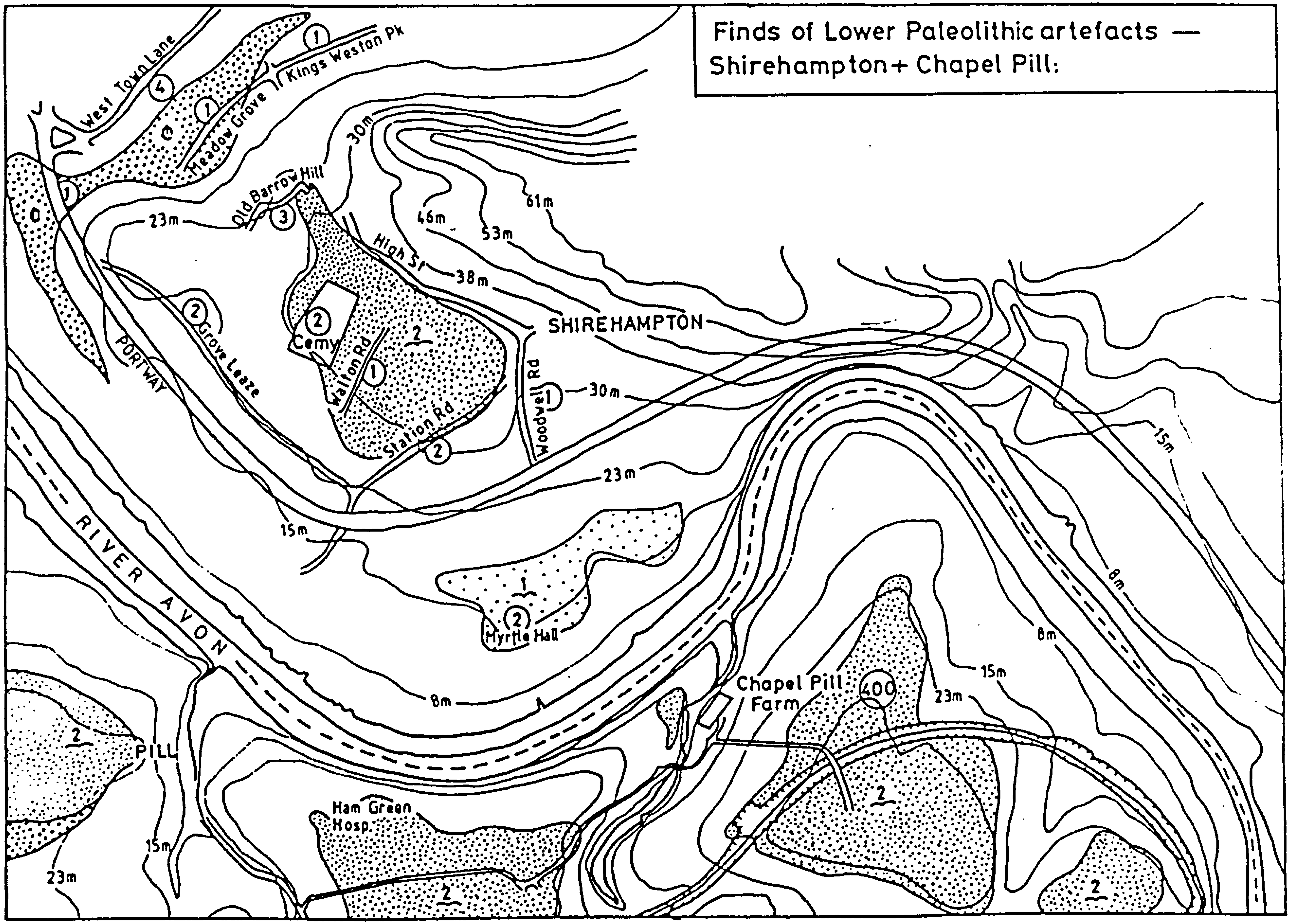

Finds of Lower Paleolithic artefacts —
Shirehampton + Chapel Pill:
West Town Lane
Meadow Grove
Kings Weston Pk
Old Barrow Hill
High St
SHIREHAMPTON
Cemy
Walton Rd
Station Rd
Woodwell Rd
Grove Leaze
PORTWAY
RIVER AVON
Myrtle Hall
Chapel Pill Farm
Ham Green Hosp.
PILL
61m
53m
46m
38m
30m
23m
15m
8m
400

Figure 6.7

surrounding the artefacts. The deposits themselves are more fully discussed in Chapters 4 and 7.

The three tools illustrated on Fig. 6.5 (Lacaille, 1954) are some of the few examples which have been recovered from within a gravel deposit, as opposed to being surface finds. Lacaille's descriptions of the deposits (recorded by Fry in 1928 in the Shirehampton Cemetery and near Myrtle Hall) are contained in Appendix I, Sections 24 and 25. The artefacts were removed from the equivalent of Bed I at Grove Leaze and Station Road (24-29m O.D.). This deposit consisted of 0.5-1.0m of reddish Marly loam, with pockets of unaltered fine Jurassic limestone gravel, with some Carboniferous Limestone, quartzite and flint.

The descriptions suggest glacial material similar to that found during the present study at Chapel Pill and the A369 ditch, Sheepway, with the incorporation of some pockets of older terrace gravel material at Shirehampton. The important point to note is that the artefacts were not removed directly from terrace material but rather a deposit which included some of this gravel.

<u>LITHOLOGICAL TYPES</u> :

The materials involved are Greensand chert, flint, quartzite, and indurated sandstone. The poor quality of the chert and its honey colour identify it as being from the Greensand chert formations, but artefacts made from it are only half the size of their equivalents from the Axe Valley in Devon (D'Urban, 1878). The origin of the Greensand chert of the tools will be subject to the same discussion as that of the gravel pebbles themselves.

The flints are from the Cretaceous Chalk, the nearest outcrop of which is in the Warminster-Westbury area of Wiltshire. The sandstone is of more local origin and probably from the Failand Ridge.

DISCUSSION :

The range of objects preserved shows that a comprehensive industry existed in this part of England in the Lower Palaeolithic. Yet when studied individually the general standard of work is unimpressive, perhaps because the makers were limited to such rough pebbles as their starting cores, instead of the fresh lumps of unworn flint more readily available in southeast England. This meant that the waste from the manufacture of axes was rarely large enough to be used for other trimmed tools i.e. the core was not prepared for secondary removals. This may be the reason that some of the tools were regarded by early workers as being Abbevillian or early Acheulian since they are thicker and heavier than those generally regarded as of the main Acheulian period.

Lacaille notes that these tools are also sometimes granulated and porous and thus, he thinks, older, though it seems also likely that they are of a different form of the Greensand chert. He admits that his idea would need more stratigraphic backup. Study of these examples proved that they are manufactured from Greensand chert Type II (as defined in Chapter 5). The resistance and character of the second chert type has resulted in the thicker, heavier tool.

Most of the artefacts are however comparable to those of the Middle gravels at Barnfield Pit, Swanscombe, and Roe (1974) classes them as the "scrag end" of a Mid-Acheulian industry.

An important point to note in studying these artefacts is that when Davies and Fry wrote their papers (1928 and 1956), some of the bifacial tools were designated as Mousterian (Ipswichian/Devensian). It was not recognised then that these core and flake tools were also made in the Acheulian, but instead were thought to be an advance on that industry. However they are known now to be part of a well-developed Mid-Acheulian industry.

The cores that have been found, from which flakes were struck, are much smaller and thinner than those from other areas (e.g. the Axe Valley), due to the use of flat pebbles rather than large nodules, and generally only one flake has been removed.

Most of the tools are affected by patination, however those taken directly from the gravels at Shirehampton are only very slightly rolled at most, in contrast to the very rolled, worn and broken finds at Chapel Pill. Again this emphasises the difference in the two deposits.

Roe (1967, 1968, and 1981) classified the British handaxe industries of the Lower Palaeolithic period into seven groups, based on their designs and manufacturing techniques. In broad terms, Groups I-III are of the "pointed" tradition, whilst V-VII are dominated by the ovate types, with Group IV being a generalised or indeterminate category.

In recording the Bristol Avon artefacts, Roe (1981 and Pers. Comm.) assigned the tools to their respective groups. During the present study it was noted that while the handaxes from Kelston, Brislington, Chapel Pill and Shirehampton are bifaces of Group II, those from Portbury were tentatively put into the Group I category.

Group I includes many pointed handaxes but also many square-ended types and cleavers. Those ovate examples found are generally of narrow dimensions. Artefacts of this group have been found at other sites including Furze Platt, Maidenhead; Baker's Farm, Farnham; Cuxton, Kent; and Whitlingham, Norfolk. On the basis of present evidence they are dated to the Late Hoxnian - Early Wolstonian, and an Inter-Wolstonian period, plus a possible occurrence in the Full Ipswichian at Stoke Newington, East London.

Group II is dominated by pointed handaxes, with cleavers and square-ended ovates rare or absent. The Group typified by those from Barnfield Pit, Swanscombe; Chadwell St. Mary, Essex; Hitchin, Hertfordshire; and Foxhall Road, Ipswich. They are regarded as probably from the Full Hoxnian and the Late Hoxnian - Early Wolstonian period.

There are known to be substantial overlaps in time between the four main handaxe Groups, and the two "pointed" and "ovate" traditions themselves span long periods and overlap considerably. However on the available evidence the Group II material dates to the Hoxnian Interglacial, with some survivals into the Early Wolstonian, whereas the Group I industry is generally a later occurrence, from the Late Hoxnian into the Wolstonian.

Although the Portbury artefacts and those from the other Avon sites cannot be definitively assigned to different industries, traditions or time ranges, there is some suggestion that they are from separate archaeological populations and may possibly date to different geological periods.

THE CONTEXT OF THE ARTEFACTS :

The following facts emerge from the study of the artefacts :

1) Most are made from Greensand chert (with only a few from Chapel Pill of quartzite, sandstone, and flint). All these lithologies are found within the Quaternary drift and alluvial deposits of the Bristol Avon catchment area. None of the tools are larger than the biggest pebbles of the same lithology within the containing deposits. It is notable that the relative percentage of the lithologies of the handaxes from Chapel Pill is similar to the percentages of the various lithologies of the gravel deposits. This may strengthen the view that the gravels were used as a source of raw material for the manufacturing of artefacts.

2) All the handaxes date to the Mid-Acheulian period (Hoxnian III to Mid-Wolstonian).

3) The tools are found at heights of
   a) c. 46m O.D. - Kelston, Brislington and St. Anne's.
   b) c. 23-30m O.D. - Chapel Pill, Shirehampton.
   c) c. 8-10m O.D. - Portbury.

4) Those from Chapel Pill are very rolled, worn and broken.
   Those from Shirehampton are moderately rolled.
   Those from Kelston, Brislington and St. Anne's are unabraded, surface finds.

5) The small sample of artefacts from Portbury may differ in their typology from those of the other sites, and include a possible Abbevillian, and hence probably derived example. The height of the deposit and state of the artefacts suggest they may be reworked examples, and have a different depositional history from the other finds.

6) The tools from Kelston, Brislington, St. Anne's, Chapel Pill (and possibly those from Shirehampton) were found associated with deposits of either soliflucted or glacial origin, in which were large percentages of Greensand chert.

Therefore the following statements can be made :

7) If the artefacts were deposited along with the gravels, then the gravel deposition postdates their manufacture, i.e. they were deposited during the Hoxnian or the Early Wolstonian at the earliest.

8) If the artefacts were made using gravel deposits as a source of raw material, and the tools represent remnants and debris of this industry, then the gravels would be of pre-Hoxnian or Hoxnian to Early Wolstonian date at latest.

9) The Chapel Pill tools are very worn and the deposit as a whole is seen as having been redeposited by solifluction or left by glacial ice. This cold period postdates the tool manufacture, since they appear to have suffered abrasion within the deposit, and must date to the Wolstonian or Devensian period. There is also some evidence at Shirehampton of disturbance and/or redeposition of terrace gravels.

Several authors (notably Wymer and Straw, 1977) have noted the correlation between the known distribution of Palaeoliths and the limits of the Ice Advances in the British Isles. From these limits it can be shown that nearly all the material lies to the south of the Devensian glacial area, the rest having been destroyed, concealed or greatly disturbed by the Devensian deposits. This process would have occurred also during the Wolstonian glacial, so that many artefacts left from the Hoxnian interglacial and Early Wolstonian period were destroyed during that advance. Those that remain are found most frequently on the fringes or to the south of the ice limits. An exception to this is the rare finding of artefacts preserved beneath till at Welton-le-Wold, Lincolnshire (Alabaster and Straw, 1975).

The Bristol Avon artefacts have been considered as a Mid-Acheulian industry associated with gravels of the Mid-Hoxnian to Early Wolstonian period. The Chapel Pill site shows heavily worn artefacts in a disturbed context of redeposition by periglacial solifluction or glacial ice. The evidence suggests that this is an area on the very fringes of an ice advance with some artefacts preserved unaltered and others incorporated within the cold phase deposits and therefore suffering abrasion and breakage.

However, there is no clue as to whether this cold phase is of Wolstonian or Devensian date. It is clear that it was not the Anglian period, since the cold phase of disturbance postdates the tool manufacture.

The following depositional history of the Bristol Avon artefacts is proposed :

1) Prior to the Hoxnian : The deposition at 46m O.D. (Brislington and Kelston) and at 30m O.D. (Chapel Pill and Shirehampton) of a gravel accumulation, probably of glacial till, which included a large percentage of coarse gravel and cobbles of Greensand chert.

2) Late Hoxnian - Early Wolstonian : The use of these gravels by Palaeolithic man for tool manufacturing, which left some artefacts and the debris of this Group II industry at the surface of the deposits. There is the possibility that the Portbury Group I handaxes may have been made at a slightly later date i.e. Late Hoxnian to Mid-Wolstonian.

3) Wolstonian or Devensian Cold Phase : The disturbance of the deposits at Chapel Pill and Shirehampton by solifluction, periglacial processes or by glaciation. This resulted in the redeposition, abrasion and breakage of some of the artefacts.

THE DISTRIBUTION OF FAUNAL REMAINS AND ARTEFACTS :

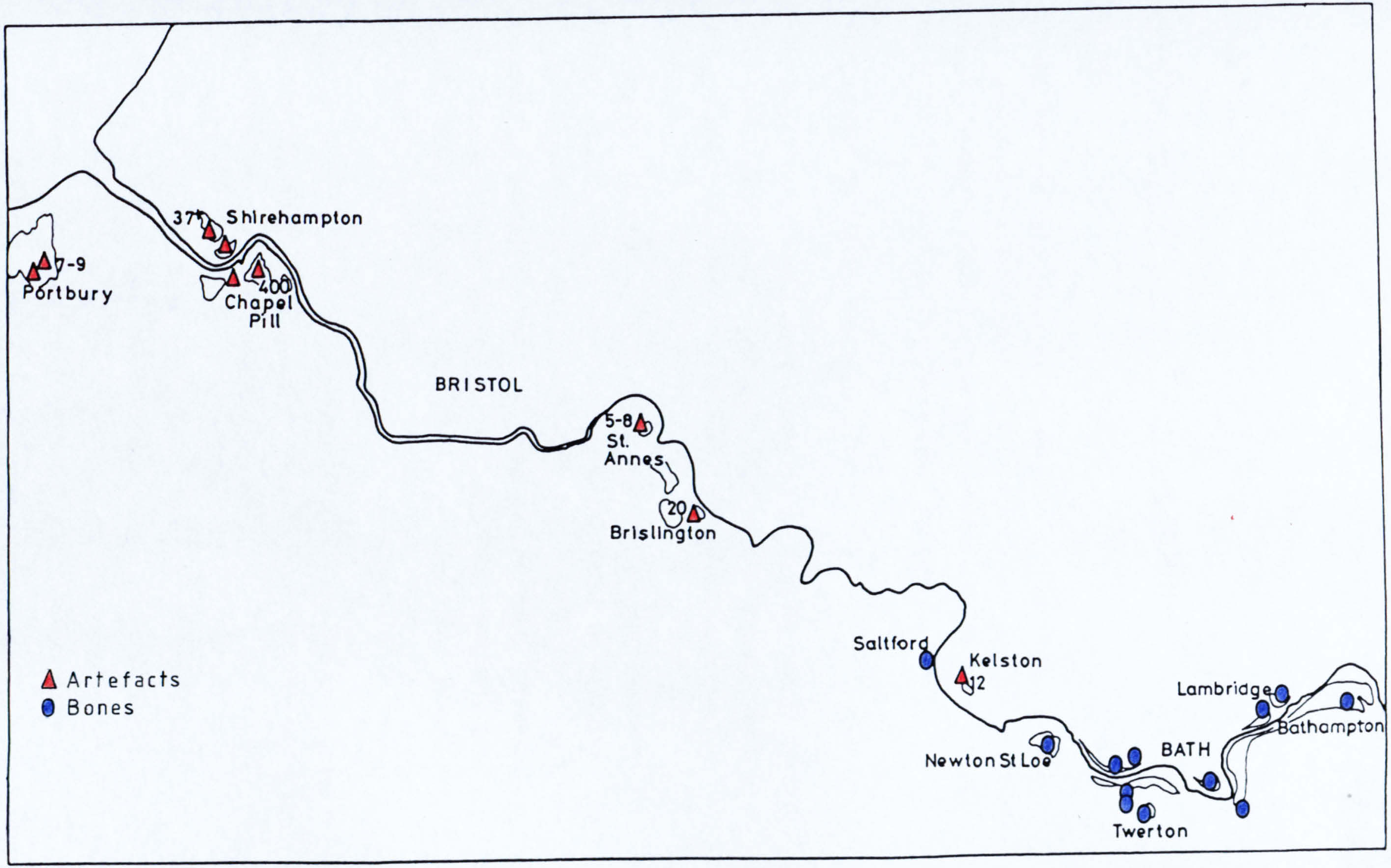
Fig. 6.8 shows the distribution of finds of faunal remains and artefacts within the River Avon valley, between Bathampton and Avonmouth. The striking point that emerges is that the two are mutually exclusive : i.e. all the bones were recovered from the fluvial gravels around Bath, while the artefacts were all retrieved downstream of Kelston, and mainly from the possible glacial deposits.

It has been suggested above that the artefacts were made near to the source areas of the best local raw material i.e. the Greensand chert of the deposits at Chapel Pill, Brislington and Kelston. They therefore represent manufacturing sites, as opposed to living sites. Their Mid-Acheulian date suggests an Anglian origin for the gravels from which the chert was obtained. These gravels lie at heights of 23-30m O.D. at Chapel Pill, and 46m O.D. at Brislington and Kelston.

Although Fry (1956) mentions "unaltered river gravel" at Kelston, and more recent evidence of this deposit exists (Chapter 2) the surface finds of artefacts from Kelston may not be related to this deposit, but rather to the chert rich gravels, marked on the British Geological Survey maps as Head material.

The faunal remains are found in the Bath gravels at 23-30m O.D. and at 46m O.D. Downstream of Keynsham the terraces are known to drop below the level of the alluvium so that the chances of recovering remains is decreased. In spite of the many exposures, the substantial deposits at Bitton, Stidham and Keynsham have yielded no remains. It would therefore appear that the apparent limitation of bones to the Bath gravels is a true one, although the reason for this is unclear. As discussed above, the faunas may suggest a Wolstonian date for the gravel terraces at Bath.

Figure 6.8 : Distribution of finds of faunal remains and Lower Palaeolithic artefacts from the Lower Bristol Avon



CHAPTER 7

THE DEPOSITIONAL HISTORY OF THE AVON VALLEY GRAVELS :

INTRODUCTION :

The previous chapters have drawn attention to the data on the gravel deposits of the Avon Valley as described in the literature, given details of the present author's fieldwork and the sedimentary analysis undertaken, and interpreted the faunal and archaeological remains.

The salient points to emerge include :

a) The deposits between the Limpley Stoke Gorge and the Conham Gorge are similar in terms of their lithologies and sedimentology. Most of the recorded faunal remains are associated with these deposits.

Typically deposition commences with a horizon of very coarse gravel to cobbles, with some boulders; this has been interpreted as a channel lag gravel (e.g. Victoria Pit, Bath; Stidham Pit C). Above these lag gravels is an unstratified mixture of material dominated by local Jurassic limestones, with subsidiary amounts of sand and mud. Upwards, some of the exposures became more stratified, with layers of finer gravel intercalated with lenses of sand.

b) Downstream of the Conham Gorge no examples of true "terrace gravels" have been observed during this research, despite many references in the literature to terrace gravels in this area.

Examination of the deposits at Chapel Pill, both in the field and sedimentology laboratory, indicate they are more typical of a glaciogenic origin. A reinterpretation of the literature on the Shirehampton deposits also suggests that they are more likely to be glacial material.

The Sheepway and A369 ditch gravels overlie glacial till and are affected by periglacial phenomena. This, together with their very poor sorting and lithological content, indicates that it is highly probable that they are the products of fluvioglacial streams.

c) The Lower Palaeolithic implements found in the Avon Valley were made mainly from Greensand chert and flint. They are recorded from areas of deposits in which these rock types are prominent, and which are interpreted as being of glacial origin. Few implements are associated with gravels which could be considered as true terrace material.

PROPOSED DEPOSITIONAL HISTORY :

In Chapter 2 the known depths to bedrock along the course of the Lower Bristol Avon were used to produce a diagram showing the bedrock channel and its associated basal gravels. These have been drawn relative to the height of the modern alluvium in Fig. 2.1. The levels and positions of the "terrace gravels" can now be added to this diagram in Fig. 7.1.

A combination of factors have resulted in the concentration of terrace material around the city of Bath. The physiographic setting at Bathampton, where the River Avon is joined by the Bybrook, Lambrook and Swainswick streams has been discussed in Chapter 4. Upstream these tributary valleys are relatively constricted and indeed the River Avon has been confined by the Middle Jurassic strata in the Limpley Stoke Gorge. As the streams emerge into the more open valley at Bathampton, the resultant loss of transporting power has caused the accumulation of gravel deposits. An additional factor is the availability of debris from the unstable slopes in the district.

After being restricted again through the Bath Valley, the Avon reaches a further area of broad floodplain around Newton Meadows. Here the gravel deposits are less extensive, probably due to the fact that most of the available material has been deposited.

In the Saltford-Keynsham area are several large spreads of gravel. These are situated close to the confluence of the Rivers Boyd and Chew with the Avon. It is likely therefore that they were formed largely from material transported by these tributary streams. This has been shown to be the case at Stidham, where Carboniferous rocks carried downstream by the River Boyd form an important constituent of the terrace deposit.

Figure 7.1 : The positions and altitudinal ranges of the gravel deposits of the Lower Bristol Avon Valley

Downstream of Keynsham no further comparable terrace material is found. Although none would be expected in the narrow gorge areas of the valley at Conham and Clifton, some would be anticipated in the broad low lying area of Bristol between Netham and Hotwells, and again downstream of the Clifton Gorge. It has been suggested already that the thick alluvium (up to 12m in the Bristol basin) would conceal any terrace material or bench levels. It is as likely, however, that the initial shortage of material from the Jurassic uplands and the rejuvenation in the Wolstonian and Devensian as the Avon incised to a new base level has resulted in a lack of preserved terrace deposits.

A higher sea level with wave heights of 14-20m O.D. during the Ipswichian period would have flooded and "scoured" the lower reaches of the valley as far as the Conham Gorge area.

Taking all these factors into consideration the following depositional history for the gravel deposits of the Avon Valley is proposed :

<u>FLANDRIAN TEMPERATE PERIOD</u> : (10,000 - 5,000 years BP)

- Initially a rapid rise in sea level causing a "ponding" effect in the Bristol, Keynsham and Bath lowlands, and the deposition of grey Flandrian silts and clays over the basal gravels of the buried channel of the Avon.

<u>LATE DEVENSIAN</u> :

- Meltwater release and the incipient rise in sea level, together with the availability of frost shattered and soliflucted material, causing the deposition of coarse gravel - boulder size material in the base of the excavated Devensian channel of the Avon. Deposition of the gravels at Royal Portbury Dock between -6 to 5m O.D.
- Period of landslipping and solifluction around Bath.

DEVENSIAN GLACIAL MAXIMUM :

- Area suffering periglacial conditions with the deposition of coversands material e.g. at Portbury. Prior to this, permafrost resulting in the development of ice wedge features and cryoturbation phenomena at Portbury (and possibly at Stidham and Bathampton, although the deformation at these sites may have occurred during the Wolstonian).
- Possible glaciation of the Avon coastal area depositing first the lower grey green till found at the A369 ditch. Meltwaters during a period of ice decay or slight amelioration resulting in the deposition of the fluvioglacial gravels at the A369 and on the Sheepway rise. Possibly a further glacial resurgence depositing the upper, red brown till found in the area. The absence of any deposits between these tills and coversands, and the Flandrian alluvium above, supports the Devensian date. An older deposit would be less likely to have survived the Wolstonian and/or Devensian period at such a height and location. Glacial ice is known to have reached at least as far south as Newport and Uskmouth during this period.

MID-DEVENSIAN INTERSTADIAL :

- Meltwaters and the availability of debris from the glacial episode, together with the rising sea level as the ice sheets decayed, resulting in development of the low terrace between Bathampton and Bitton, and very likely further downstream. Terrace material deposited at 10-14m O.D. in the Keynsham area, 15-23m O.D. in Bath, and 20-30m O.D. at Bathampton.
- Little or no faunal material was incorporated in this terrace aggradation, perhaps due to the severity of the recent glacial period. Possible periglacial cryoturbation of these gravels e.g. at Bathampton. This terrace will be referred to as the "Bitton - Holm Mead" terrace from now on.

EARLY DEVENSIAN :

- Disturbance of the superficial deposits at Shirehampton and Chapel Pill by glaciation or solifluction. This resulted in the heavy abrasion of the artefacts at Chapel Pill, probably due to incorporation in glacial till, and the intercalation of pockets of terrace gravel along with some relatively unrolled artefacts in periglacial slope deposits (which included till material) at Shirehampton.
- Buried valley of the Avon recut by rejuvenation of the river to a new base level below -20m O.D. This process eroded any low level remnant terrace deposits downstream of the Conham Gorge.
- Solifluction and terrace aggradation during less severe climatic periods of the Devensian.

IPSWICHIAN :

- High sea level and marine transgression, with influence extending inland at least as far as the Conham Gorge. Flooding of the lower valley and possible scouring causing removal of some terrace materials.

LATE WOLSTONIAN :

- Terrace aggradation between Bath and Keynsham (and very likely further downstream also), with material deposited at 19-22m O.D. at Stidham, 22-23m O.D. at Newton St. Loe, 23-30m O.D. at Boyce Hill, Bath, and at 30-37m O.D. at Larkhall and Lambridge. Fauna associated with this terrace is predominantly of a cold tolerant type. This terrace will be referred to as the "Stidham" terrace from now on (Base = 20-30m O.D.).
- Cold period causing further rejuvenation and downcutting to a suggested level of 0m O.D. at Avonmouth.

WOLSTONIAN GLACIAL MAXIMUM :

- Phase of rapid downcutting seen in the upper part of the valley as a terrace slope at around 15m O.D. at Newton St. Loe, Stidham and Bitton. Suggested base level at Avonmouth of -3 to -5m O.D.

EARLY WOLSTONIAN :

- Initial cold phase and development of terrace at Twerton at 46m O.D. with an associated late Hoxnian to Early Wolstonian fauna. Possible terrace deposition at Kelston (46m O.D.) and Shirehampton (30m O.D.) (The base level for this aggradation would therefore be around 25m O.D. at Avonmouth?) This terrace will now be referred to as the "Twerton" terrace from now on. (Base = 30-50m O.D.)

LATE HOXNIAN - EARLY WOLSTONIAN :

- Mid Acheulian artefacts made at sites of chert rich gravels at Kelston (46m O.D.), Brislington (46m O.D.), Chapel Pill (30m O.D.) and Shirehampton (30m O.D.). Debris and some artefacts left at the manufacturing sites.

ANGLIAN :

- Extensive glaciation and deposition of till at various levels : Bathampton Down (and at other high level plateaux around Bath) around 140-190m O.D.; Kelston 46 and 76m O.D.; Brislington 46m O.D.; and Chapel Pill 30m O.D. Till rich in Greensand chert and Cretaceous flint.

The depositional sequence above is suggested to account for the deposits of the Lower Bristol Avon. While no attempt at a detailed correlation with other river systems is made, it is necessary to draw some general parallels between the Bristol Avon sequence and that of other catchments. Fig. 7.2 illustrates the broadly accepted outline of terrace deposition for the Thames Valley and the Rivers Severn and Warwickshire Avon, alongside those of the Bristol Avon.

	BRISTOL AVON	UPPER THAMES	LOWER THAMES	SEVERN AND AVON OF THE MIDLANDS
FLANDRIAN	Alluvial silts		Tilbury aggradation	
LATE DEVENSIAN	Basal gravels Coversands & periglacial cryoturbation		Ponder's End & 3rd buried channel infills	Avon No. 1 and Power House terraces Worcester Terrace
GLACIAL MAXIMUM	Sheepway tills and gravels			
MID-DEVENSIAN	Holm Mead Terrace	Floodplain Terrace	Lower Floodplain Terrace	Avon No. 2 and Main Terrace
EARLY DEVENSIAN	Buried channel cut			Avon No. 4 and Kidderminster Terrace
IPSWICHIAN		Eynsham gravel Stanton Harcourt gravel	Upper Floodplain Terrace	Avon No. 3
LATE WOLSTONIAN	Stidham Terrace	Woolvercote Terrace	Taplow Terrace	Avon No. 5 and Bushley Green Terrace
EARLY-MID WOLSTONIAN	Twerton Terrace		Lynch Hill Terrace	Upleadon and Woolridge Terrace
HOXNIAN	Artefacts made from Anglian tills		Boyn Hill Terrace	
ANGLIAN	Glacial till	Hanborough Terrace	Black Park and Kingston Leaf Terrace	

Figure 7.2 : Outline correlation of terrace gravels from the Lower Bristol Avon, the Upper and Lower Thames, and the Severn and Avon of the Midlands

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APPENDIX I : SECTIONS QUOTED IN THE TEXT OF CHAPTERS 2 and 4

SECTION 1 : BATHFORD OOLITIC QUARRY

Winwood (1978)

5.	Humus	(0.28m)
4.	Oolitic debris	(0.58m)
3.	Solid Oolite bed	(0.25m)
2.	Flint pebbles	(0.45m)
1.	Rag beds	(0.35m)

Height : c. 529 ft above Avon (182m O.D.)

SECTION 2 : BOX VALLEY

Woodward (1876)

5.	Brown clay	(0.3m)
4.	Gravelly loam	(1.2-1.5m)
3.	Stiff yellow loam, gravelly at base	(0.23m)
2.	Grey pipe clay seam	
1.	Gravel	(1.5m)

SECTION 3 : LARKHALL

Woodward (1876)
Moore (1869)

5.	Oolitic and Up. Lias gravel	(4.5m)
4.	Mottled brownish clay	(0.9m)
3.	Blue clay	(0.45m)
2.	Mottled brownish clay	(0.9m)
1.	Gravel	(2.4m)

SECTION 4 : PULTENEY ROAD, BATH

Moore (1870)

		21.1m O.D.
8.	Yellow, mottled brickearth	(3.6m)
7.	Fine laminated clays w. shells and organic remains	(2.1m)
6.	Black band (peat?)	(0.1m)
5.	Gravel	(0.23m)
4.	Blue marl	(0.1m)
3.	Light fine sand	(0.1m)
2.	Mammaliferous drift gravels	(3.6m) (14.9m O.D.)
1.	Lower Lias clays	

SECTION 5 : ROYAL HOTEL/GRAND PUMP ROOM — Moore (1870)

4.	Made ground, drifted marl	(3.6m)	—— 24.36m O.D.
3.	Freshwater alluvial clays	(2.4m)	
2.	Mammaliferous drift gravels	(1.2)	——
1.	Blue Lias clay		17m O.D.

SECTION 6 : MOREFIELD CUTTING — Winwood (1874)

Height: 89 ft above Avon (45.66m O.D.)

7.	Humus and Oolitic wash	(0.28m)
6.	Sand	(0.07m)
5.	Gravel	(0.28m)
4.	Yellow arenaceous clay	(0.07m)
3.	Gravel with lenses of 4.	(1.06m) ---- mammals
2.	Large Inf. Oolite boulders & blocks of Greensand	(1.7m)
1.	Light blue clay with Ironstone	(3.46m total)

SECTION 7 : VICTORIA GRAVEL PIT — Winwood (1888)

Height: c. 100 ft above Avon (48 m O.D.)

10.	Reddish loam with Romano-British Pottery	(0.48m)
9.	Gravel	(0.53m)
8.	Sand lens	(0.05m)
7.	Gravel	(0.25m)
6.	Black band	(0.05m)
5.	Gravel	(0.1m)
4.	Black band	(0.02m)
3.	Irony coloured gravel	(0.17m)
2.	Ditto, coarser with black bands and mottled clay containing mammalia	(0.5m)
1.	Light Blue clay with large sandstone and Oolite blocks at top	(1.65m total)

SECTION 8 : BOYCE HILL, N/S SECTION, North End — Winwood (1897)

5.	Turf and mould	(0.12m)	
4.	Disturbed White Lias & yellow clay	(0.62m)	
3.	Yellow clay	(0.25m)	
2.	Sandy clay with pebbles	(1.06m)	Total 2.05m
1.	Rubbly White Lias	(1.2m)	

SECTION 9 : BOYCE HILL, SOUTH END

Winwood (1897)

6.	Turf and mould	(0.20m)	
5.	Reddish loam and burnt earth	(0.4m)	
4.	Clay resting on	(0.1m)	
3.	Gravel	(0.30m)	Total 1m
2.	Rubbly White Lias	(0.75m)	
1.	Solid White Lias	(0.17m)	

SECTION 10 : BOYCE HILL, SOUTHEAST END

Winwood (1897)

Height: gravels c. 37 ft above Avon (= c. 30m O.D.)

5.	Top turf and soil	
4.	Clay with stones and subangular blocks of Lr. Lias, reddish brown at base & resting on irregular, wavy surface	(0.42m)
3.	Mottled grey & reddish marl, graduating into	(0.38m)
2.	Sandy marl streaked brownish red and yellow, with small pebbles, gradually passing into gravel with large blocks of grit at base	(1.52m)
1.	White Lias	2.32m total

SECTION 11 : LONDONDERRY WHARF, KEYNSHAM

Donovan (1960)

——— 10.36m O.D.

5.	Clayey loam with soil above	(1.52m)
4.	Brown clay	(1.52m)
3.	Brown sand, with shells and some clay	(1.52m)
2.	Grey silt with shells and wood	(1.67m)
1.	Gravel with large stones, bottom not reached	(0.91m)

SECTION 12 : KEYNSHAM HAMS (Bypass) B1

Donovan (1960)

——— 10.66m O.D.

7.	Red brown silty clay	(0.6m)
6.	Light brown sandy and silty clay with some coarse gravel in upper 1.2m	(1.52m)
5.	Red brown clayey sand and gravel	(0.6m)
4.	Angular fragments of sandstone	(0.3m)
3.	Red brown silty clay with a few sandstone fragments	(0.9m)
2.	Brown sandy silt with coarse sand & gravel, & angular fragments of sandstone at top	(1.97m)
1.	Yellowish silty sand & gravel, bottom not reached	(0.30m)

SECTION 13 : KEYNSHAM HAMS (Bypass) R3 — Donovan (1960)

		8.84m O.D.
3.	Light brown slightly silty clay with a few small sandstone fragments	(3.04m)
2.	Light brown, clayey, silty sand with angular gravel	(0.91m)
1.	Fine & medium sand & gravel, with a little silt, bottom not reached	(2.13m)

SECTION 14 : KEYNSHAM HAMS (Bypass), R4 — Donovan (1960)

		9.3m O.D.
3.	Light brown clay	(2.3m)
2.	Grey & red silty & sandy clay, & gravel. Peaty material at top	(0.45m)
1.	Yellowish brown gravel & silty sand in part clayey, bottom not reached	(0.30m)

SECTION 15 : KEYNSHAM HAMS (Bypass), R5 — Donovan (1960)

		9.1m O.D.
3.	Brown very sandy & silty clay with pebbles	(1.2m)
2.	Yellowish brown sand & gravel, slightly silty & clayey in parts	(4.87m)
1.	Stiff grey clay, Rhaetic/Lr. Lias?	(0.60)

SECTION 16 : RIVER CHEW — Donovan (1960)

		9.7m O.D.
4.	Reddish brown slightly clayey silty fine sand	(2.13m)
3.	Brown clayey silt,sandy in parts with thin peat layers	(1.2m)
2.	Poorly graded angular gravel with slightly silty medium & coarse sand	(2.13m)
1.	Grey silty shaly clay, Rhaetic?	

SECTION 17 : JERSEY AVENUE, BRISLINGTON (SE end) — Fry (1956)

		55m O.D.
3.	Surface soil with worn pebbles of Greensand chert	(0.30m)
2.	Yellow-grey clay with scattered pebbles of Greensand chert & flint	(1.62m)
1.	Bedrock - Coal Measures	(1.03m)

SECTION 18 : JERSEY AVENUE, BRISLINGTON (NW end) — Fry (1956)

3.	Surface soil with river-worn pebbles	(0.30m)	
2.	Red sandy loam with scattered pebbles of chert and flint, v. iron rich	(0.96m)	
1.	Bedrock - Coal Measures	(1.03m)	

SECTION 19 : LAWFORD'S GATE, BRISTOL — Fry (1956)

			13.7m O.D.
4.	Made ground	(0.69m)	
3.	Red loam with occasional pebbles of Greensand chert, some w. thermal fracture	(0.68m)	
2.	Red sandy loam	(0.83m)	
1.	Grey quartzose sand	(1.37m)	

SECTION 20 : BROADMEAD, BRISTOL — Fry (1956)

			8.21m O.D.
5.	Soil and made ground	(1.06m)	
4.	Marsh clay with landshells, roots	(1.2m)	
3.	Estuarine clay, fine, upper 4m greenish becoming light brown	(5.9m)	
2.	River gravel, mainly green Pennant Sandstone with limonite and a few Lias pebbles and Mesozoics	(1.3m)	(-1.2m O.D.)
1.	Keuper Marl	(1.15m)	

SECTION 21 : CUMBERLAND BASIN — Stoddart (1870)

4.	Gravel with red deer, freshwater shells, rhino, horse, oak		
3.	Stiff brown clay	(1.2m)	
2.	Gravel	(1.8m)	
1.	Red Marl		

SECTION 22 : CHAPEL PILL FARM — Lacaille (1954)

4.	Sandy soil with fragments of chert	(0.35m)	
3.	Unstratified detritus from decalcified gravel	(0.30m)	
2.	Loam mixed with Trias clay	(0.15m)	
1.	Trias Marl	(0.80m	total)

SECTION 23 : HIGH STREET, SHIREHAMPTON — ApSimon & Boon (1960)

		——— 33.5m O.D.
7.	Tarmac	(0.23m)
6.	Light red-brown clayey sand with occasional small stone fragments passing into 6a below	(0.37-0.45m)
6a.	As 6 but with yellow sandstone fragments and sand from layer below	(0.30m)
5.	Pale yellow earthy sand apparently horizontally bedded	(0.07-0.23m)
4.	Reddish brown sand, more earthy than 5, horizontally laid, small gravel stones in top 0.10m	(0.20-0.25m)
3.	Pale yellow earthy sand, horizontal, sharp transition with 4	(0.02-0.15m)
2.	Gravelly earth, top 0.2m fine gravel with sandy matrix similar to 3. Stones relatively well rounded, < 0.10m, no large blocks. Local sandier bands, not really stratified. Most pebbles flat and horizontally lain. Mainly Jurassic limestone with flint and chert	(1.2m) with 1
1.	Small chert & limestone gravel with some earth and sand	Total = 2.5m
		——— 31.0m O.D.

SECTION 24 : SHIREHAMPTON CEMETERY — Lacaille (1954)

		——— 33.2m O.D.
4.	Red loam with broken flint & chert nodules	(0.6m)
3.	Red sandy clay with large semi-rounded blocks of Millstone Grit, Carboniferous Limestone, and Greensand chert	(0.90m)
2.	Interbedded seams of red and white quartzose sand	(0.30m)
1.	Fine limestone gravel, mainly Jurassic origin, with some Carboniferous Limestone, quartzite and flint	(0.9m) 30.5m O.D.

SECTION 25 : MYRTLE HALL, SHIREHAMPTON — Lacaille (1954)

		——— 18.25m O.D.
3.	Soil and subsoil with chert, quartzite and haematite pebbles	(0.6m)
2.	Coarse sandy loam, unstratified	(0.3m)
1.	Reddish marly loam mixed with gravel, with pockets of unaltered gravel, mainly Jurassic	(0.6m) 16.75m O.D.

PORTBURY BOREHOLE SERIES

PORTBURY 3 : (ST 4937 7633)

			11.58m O.D.
3.	Clayey topsoil	(0.31m)	
2.	Firm brown Marl with scattered gravel	(1.98m)	
1.	Firm red Marl		9.29m O.D.

PORTBURY 4 : (ST 4932 7700)

			14.02m O.D.
4.	Made ground	(0.32m)	
3.	Firm, brown, very sandy clay	(0.9m)	
2.	Gravel and sandy clay	(1.53m)	11.27m O.D.
1.	Very stiff, red/grey mottled Marl		

PORTBURY 5 : (ST 4887 7630)

			10.36m O.D.
3.	Stoney topsoil	(0.46m)	
2.	Gravel and sandy clay	(0.46m)	9.44m O.D.
1.	Very stiff red and grey mottled Marl		

PORTBURY 17 : (ST 4861 7634)

			10.36m O.D.
3.	Topsoil	(0.46m)	
2.	Firm brown silty clay with stones	(0.76m)	
1.	Stiff red Marl		9.14m O.D.

PORTBURY 24 : (ST 4890 7654)

			13.41m O.D.
4.	Topsoil	(0.46m)	
3.	Firm or stiff red brown silty clay with a few stones	(1.37m)	
2.	Sand and gravel	(1.53m)	
1.	Stiff red Marl		10.05m O.D.

PORTBURY 25 : (ST 4907 7641)

		———	13.41m O.D.
3.	Topsoil	(0.77m)	
2.	Firm brown/grey mottled sandy clay with thick bands of silty sand and stones at some levels	(1.98m)	
1.	Stiff red Marl	———	10.66m O.D.

PORTBURY 26 : (ST 4920 7673)

		———	12.8m O.D.
3.	Topsoil	(0.31m)	
2.	Firm light brown fissured silty clay	(0.91m)	
1.	Stiff red Marl	———	11.58m O.D.

PORTBURY 29 : (ST 4941 7680)

		———	9.14m O.D.
5.	Topsoil	(0.46m)	
4.	Firm, red-brown fissured silty clay with occasional stones	(1.67m)	
3.	Firm, brown silty clay with occasional veins of sand	(1.07m)	
2.	Soft, brown, very sandy and silty clay with bands of peat at lower levels	(2.59m)	
1.	Stiff red Marl	———	3.35m O.D.

APPENDIX II : MOLLUSCAN REMAINS

The molluscan fauna were kindly identified by Dr. D.D. Gilbertson as follows :

BATHAMPTON TP18	Sample 2	Sample 3	Sample 4
Valvata cristata (Muller)	2	-	-
Valvata piscinalis (Muller)	22	3	-
Bithynia tentaculata (L)	12	-	-
Bitentaculata opercula	1	-	-
Carychium tridentatum (Risso)	-	-	-
Lymnaea truncatula (Muller)	1	-	-
Lymnaea peregra (Muller)	7	-	-
Anisus leucostoma Miller	?1	-	?1
Gyraulus laevis Alder	?1	-	-
Gyraulus albus (Muller)	1	-	-
Planorbis crista (L)	1	-	-
Planorbis spp.	11	3	1
Ancylus fluviatilis (Muller)	1	-	-
Vallonia pulchella (Muller)	-	1	1
Vallonia spp.	-	1	-
Clausiliidae	3	8	1
Trichia hispida (L)	-	1	-
Punctum pygmaeum (Draparnaud)	-	-	-
Discus rotundatus (Muller)	6	16	-
Zonitidae	2	6	1
Deroceras spp.	2	-	-
Pisidium spp.	1	-	3

NEWTON ST. LOE : TP8/Sample 2

Carychium sp.	
Vallonia pulchella (Muller)	1
Trichia hispida (L)	5
Trichia sp.	1

\+ many fragments of ?Jurassic taxa.

KEYNSHAM : TP9/Sample 5

Valvata cristata (Muller)	1
Valvata piscinalis (Muller)	30
Bithynia tentaculata (L)	1
Carychium tridentatum (Risso)	4
Lymnaea truncatula (Muller)	9
Lymnaea palustris (Muller)	2
Lymnaea peregra (Muller)	7
Planorbis vortex (L)	5
Anisus leucostoma Millet	?1
Gyraulus albus Muller	29
Planorbis spp.	2
Oxyloma cf. pfeifferi Rossmassler	9
Vertigo sp.	2
Vallonia pulchella (Muller)	4
Cepea spp.	3
Trichia hispida (L)	2
Discus rotundus (Muller)	1
Zonitidae	2
Pisidium spp.	17

APPENDIX III LOWER PALAEOLITHIC ARTEFACTS FROM THE BRISTOL AVON GRAVELS

KELSTON : Fields W. of church, 46m O.D., surface finds. ST 693667.

12 found, of Greensand chert, with a light ochreous patina, only one abraded. Bifaces of Group II

UBSS Mus. (University of Bristol Spelaeological Museum)

1 disc with a broken edge.	Fig. 6.4, no. 1
1 small, coarse, square ended, irregular handaxe with a rather tapering butt	Fig. 6.4, no. 2
1 triangulate handaxe with a thick trimmed butt	Fig. 6.4, no. 3
1 small flake, ? retouched, damaged platform	Fig. 6.4, no. 4
1 wedge shaped handaxe	Fig. 6.4, no. 5

Refs.: T.R. Fry, Proc. Univ. of Bristol Spelaeol. Soc., Vol. 7, no. 3, 121-129.

BRISLINGTON HOUSE : Plateau above R. Avon, 46m O.D., surface finds. ST 635704

20 found, of Greensand Chert, with a dense ochreous patina, and no abrasion. Bifaces of Group II

UBSS. Mus.

1 triangulate handaxe with a thick angular partly trimmed butt	Fig. 6.4, no. 1
1 chert triangulate pointed handaxe on a pebble butt	Fig. 6.4, no. 2
1 square ended handaxe with a heavy untrimmed butt	Fig. 6.4, no. 3
1 small chopping tool	Fig. 6.4, no. 4
1 rolled chert flake with ? a plane platform and steep retouch	Fig. 6.4, no. 5
1 small narrow flake tool with a prepared striking platform	Fig. 6.4, no. 6
+ 1 small squat very rough, rolled ovoid handaxe, damaged	
1 slightly rolled chert flake fragment with some rough trimming	
1 small chert pyriform, square ended, possibly a coarse tranchet finish	

Refs.: T.R. Fry, Proc. Univ. Bristol Spelaeol. Soc., Vol. 7, no. 3, 121-129.

ST. ANNE'S, BRISLINGTON : 18-46m O.D., from a thin scatter of surface gravel ST 623725

8 found, Bifaces of Group II , of unabraded Greensand chert.

1 small handaxe, thick section, with grey patina and iron staining	Fig. 6.4, no. 4
1 perfect Acheulian handaxe, planoconvex section	Fig. 6.4, no. 5

Refs.: Davies & Fry, 1928, Proc. Univ. Bristol Spelaeol. Soc., Vol. 3, no. 3, 162-172.

EASTON-IN-GORDANO : Surface finds from gravel ST 515750

A few possible Palaeolithic flakes

PORTBURY-SHEEPWAY : Surface finds from gravel, 9-10m O.D. ST 494764

6 originally, Bifaces of Group I?

Sheepway Farm : UBSS Mus.

1 flattened handaxe, unabraded, coarsely chipped, with dense grey patina, + some remnant cortex — Fig. 6.5, no. 1

1 rostrate handaxe, much abraded, ochreous brown patina — Fig. 6.5, no. 2

1 square ended handaxe, coarsely chipped, unabraded, dense green-brown patina — Fig. 6.5, no. 3

\+ 1 fine evenly flaked triangulate handaxe, abraded and lustrous with an ochreous patina

\+ 1 chert flake, plane platform, very rolled, some retouch

Refs.: T.R. Fry (1956) Proc. Univ. Bristol. Spelaeol. Soc. Vol. 7, no. 3, 121-129.

SHIREHAMPTON : General area, in gravels and soliflucted derivatives, mainly surface finds, some in situ in Limestone gravels.
Bifaces of Group II , flakes of Group IV, Mid-Acheulian. c. ST 527770

National Museum of Wales, Cardiff :

1 small coarse pointed chert tool, slightly rolled, white patina.

Bristol City Museum :

1 possible side scraper, coarse, ovoid chert, cortex flake - exact location unknown
1 very heavily rolled tiny chert biface with some cortex - exact location unknown
1 chert fragment with some mechanical scars - from Parish Hall
1 small slightly rolled freshly broken handaxe fragment of flint - from Walton Road
1 very small chert rough blunt pointed handaxe, pebble butt, slightly rolled, from Station Road, 26m O.D. Fig. 6.5, no. 3
1 small rolled chert core fragment - from West Town
1 rolled chert unifacial scraper or chopper - from West Town
q small square ended handaxe, chert, moderately rolled, tranchet finish on 1 side - from Grove Leaze, 29m O.D. Fig. 6.5, no. 1
1 very rolled chert pebble, ?worked - from Shirehampton Cemetery
1 rolled shiny ? worked fragment - from Myrtle Hall
1 ? side scraper, coarse and very rolled - from Myrtle Hall
1 medium-large coarse flint handaxe, moderately rolled, roughly oval, "Abbeville" type, - 30m O.D. - Old Barrow Hill
1 rough core, chert, moderately rolled - 30m O.D., Old Barrow Hill
1 small broken chert handaxe, unrolled, unrefined point on pebble - from 29m O.D., Old Barrow Hill
1 small, very coarse chert point, very rolled - from Portway, 12m O.D.

UBSS Mus. (Shirehampton area) :

1 chert flake, small-medium, slightly rolled
2 rolled worked fragments
1 slightly rolled handaxe fragment
1 core fragment
1 anciently broken, small-medium handaxe
2 flakes, age uncertain
1 fresh disc-like chert flake, 100 O.D. Fig. 6.5, no. 9
1 slightly rolled flake with a plane platform and some retouch
1 small box of flakes from Shirehampton and Chapel Pill
1 small slightly rolled, narrow irregular square ended chert handaxe
1 small chert, squat triangulate point, coarse, pebble butt
1 small irregular point, plano-convex, damaged fragment

1 small handaxe, pebble butt, slightly rolled, coarse,
flint - from King's Weston Park

1 very rolled chert flake, retouched as a point and
scraper - from Cotswold Estate

1 small ovate handaxe neat but pebble butt and cortex,
rolled - from Cotswold Estate

1 small coarse chert handaxe, pebble butt - from Woodwell Road

Unknown number of tools, found by R. Hughes - Meadow Grove

1 handaxe found by G.C. Boon & J.C. Brown - Lawrence Weston,
Roman Villa site

1 small rolled, irregular, pointed, chert handaxe, pebble
butt - from New School site

1 ? worked chert pebble from Myrtle Hall

Unknown number found by R. Hughes from Station Hill

CHAPEL PILL : Mainly surface finds, probably derived from deposits disturbed by solifluction or glaciation 23-30m O.D.

Bifaces of Group II , flakes of Group IV, cores - Mid-Acheulian.

UBSS Museum :

1 small box of flakes from Chapel Pill and Shirehampton
1 piece of chert off a large core
1 piece of flint off a large core
1 small hemispherical core, very rolled
1 rolled, worked fragment (thermally damaged)
3 rolled chert flakes
1 chert flake fragment with retouch

Handaxes :

1 small irregular triangulate point of chert on a pebble butt
1 very small and coarse triangulate point of chert on a pebble butt
1 small neat but unrefined, triangulate point on a pebble butt
1 broad, curved handaxe on a square pebble butt
1 very small, very rolled, plano-convex, ? rough handaxe
1 very rolled, trinagulate chert point with a pebble butt
1 small, rolled, damaged, coarse, rather pointed ovoid
1 rolled small-medium broad point on a square ended chert pebble
1 broad semi-circular axe on a flat pebble butt
1 small, coarse, very rolled pointed ovate
1 small-medium, rolled chert point with a roughly-worked butt
1 small, coarse, rolled, triangulate point on a rough pebble butt
1 small, very rolled, ovate with a truncated butt
1 small, triangulate point, rather plano-convex, with a pebble butt

Bristol City Museum :

27 small, coarse, possible handaxes, sharpened pebbles at best
27 irregular, crude pebble/rough butts, many damaged
17 similar rough butts
21 miscellaneous worked fragments, including handaxe fragments
18 small, coarse pebbles - possibly "Eolith"-type handaxes
33 retouched flakes, miscellaneous
140 unretouched flakes, miscellaneous

Possible Levallois material :

1 tiny coarse core
1 small flake, ancient broken, clear faceted platform and 3+ scars - Levallois
1 small, very rolled, struck tortoise core on chert pebble
1 small similar tortoise core with facetting
1 small tortoise core or one flake core

Miscellaneous :

7 worked chert pebbles
11 worked chert fragments
1 worked flint fragment
1 worked quartzite fragment

Cores :

1 irregular flat chert core
1 small disc-like, possible core

Unretouched flakes :

3 bladelike flakes
1 damaged oval, cortex platform
1 small flake
2 flint plane platform
1 very rolled, coarse plane platform
3 chert flakes

Retouched flakes :

3 flint flakes
2 elongate, narrow, steeply trimmed, flake
1 tiny ? side scraper
1 flint
2 small flakes - ? handaxe trimmers, platforms, could be facetted

Handaxes :

1 much rolled, small, triangulate quartzite point, damaged, rough butt
1 small, slightly rolled, pointed pyramidal/ovoid flat, sedimentary axe
1 small, moderately rolled, rough triangulate chert point, pebble butt
1 small-medium, coarse, very rolled, ovate
1 small, slightly rolled, irregular point on a pebble butt
1 small, moderately rolled irregular ovate, fairly broad, coarse
1 small, slightly rolled biface, coarse, irregular and damaged
1 squat, slightly rolled, thick coarse irregular pointed pyramidal axe
1 flattish, very rolled, slightly damaged unrefined ovate with some cortex
1 flattish, very rolled, pyramid with rough butt, and cortex
1 coarse, flat handaxe (said to be on a discarded core)
1 tiny, coarse, twisted chert ovate, formerly a flake
1 elongate narrow point on a rough flint pebble butt
1 small-medium point on a rough, damaged flint butt
1 small twisted, damaged flint ovate
1 small, broken chert ficron with a rough pebble butt
1 small, squat, broad point on a tapering chert pebble butt
1 small, elongate, narrow point on a rough butt with some cortex
1 small, elongate, coarse, triangulate point, rough with a pebble butt
1 very small, flat, very coarse chert point on a pebble butt
1 very small, irregular, coarse point, with some cortex and some rough working at butt
1 handaxe fragment, roughly worked chert pebble butt
5 possible rough handaxes, very coarse, rolled, unworked butts
1 small, rough point on a pebble butt
1 squat, irregular, broad, pointed triangulate/ovoid, chert, rough worked butt
1 triangulate point on a rough chert butt
1 broad, squat, handaxe, rough on a chert pebble butt
1 tiny, coarse irregular trinagulate, chert point
1 slightly damaged, ? unfinished, pyramidal chert, with much cortex
1 tiny, broad, ovate chert point, butt and lower part all cortex

1 small-medium, triangulate/pyramidal chert point with a rather plano-convex rough butt and some cortex
1 flat, pyramidal chert point (slight damage on butt) (unfinished)
1 coarse, irregular, diamond shape, chert with pebble butt and some cortex
1 very small, flattish, irregular, damaged chert ovate
1 large, very coarse, chert pebble worked to rough but clear point

<u>HAM GREEN FARM :</u> ST 533756

UBSS Mus.

1 flint flake with some cortex and one facet only on platform.

APPENDIX IV

Examples of computer print outs of sedimentological analyses :

a) Grain size analysis : Bathampton TP14 Sample 8
Gatcombe TP33 Sample 16
A369 ditch Sample 4

b) Morphometric analysis : Chapel Pill TP7
Chert Type I sample

Grain Size Analysis

Station Number = baton 14/8

PHI SIZE	%	PHI SIZE	%
+ 9.00	99.269	+ 2.00	86.063
+ 8.00	98.994	+ 1.00	81.143
+ 7.00	98.446	+ .00	78.437
+ 6.00	95.553	- 1.00	76.125
+ 5.50	95.065	- 2.00	72.327
+ 5.00	93.908	- 3.00	64.519
+ 4.50	93.238	- 4.00	41.367
+ 4.00	92.769	- 5.00	17.246
+ 3.00	90.131	- 6.00	3.307

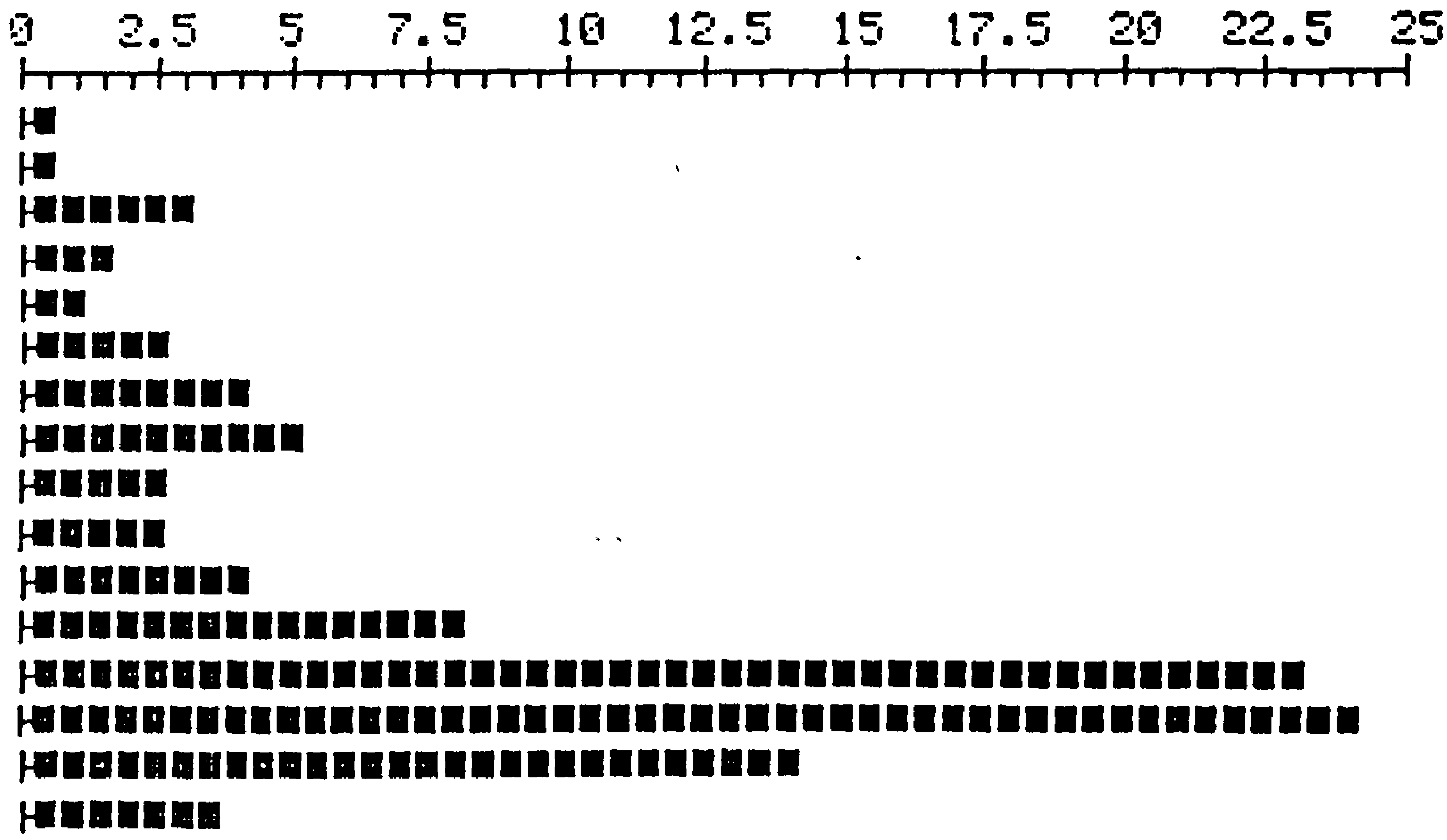
PERCENTILES		PERCENTILE STATISTICS			
5 %	- 5.87	TRASK MEDIAN	MD	-	3.627
16 %	- 5.08	INMAN MEAN	MO	-	1.754
25 %	- 4.67	FOLK MEAN	MZ	-	2.378
50 %	- 3.62	INMAN SORTING	SO	+	3.335
75 %	- 1.29	FOLK SORTING	SI	+	3.387
84 %	+ 1.58	FOLK KURTOSIS	KG	+	1.375
95 %	+ 5.47	INMAN KURTOSIS	KO	+	.701
		INMAN SKEWNESS	A1	+	.561
MOMENT STATS		INMAN SKEWNESS	A2	+	1.026
MEAN	- 2.48	INMAN SKEWNESS	A2/A1	+	1.828
STD DEV	+ 3.31	FOLK SKEWNESS	SK1	+	.582
KURTOSIS	+ 3.90				
SKEWNESS	- 1.33				

% MUD	< 4 PHI =	7.230
% SAND & GRAVEL	> 4 PHI =	92.769

STATION NUMBER BATON 14 8

HISTOGRAM OF WHOLE SAMPLE

1 DIVISION EQUALS .5%

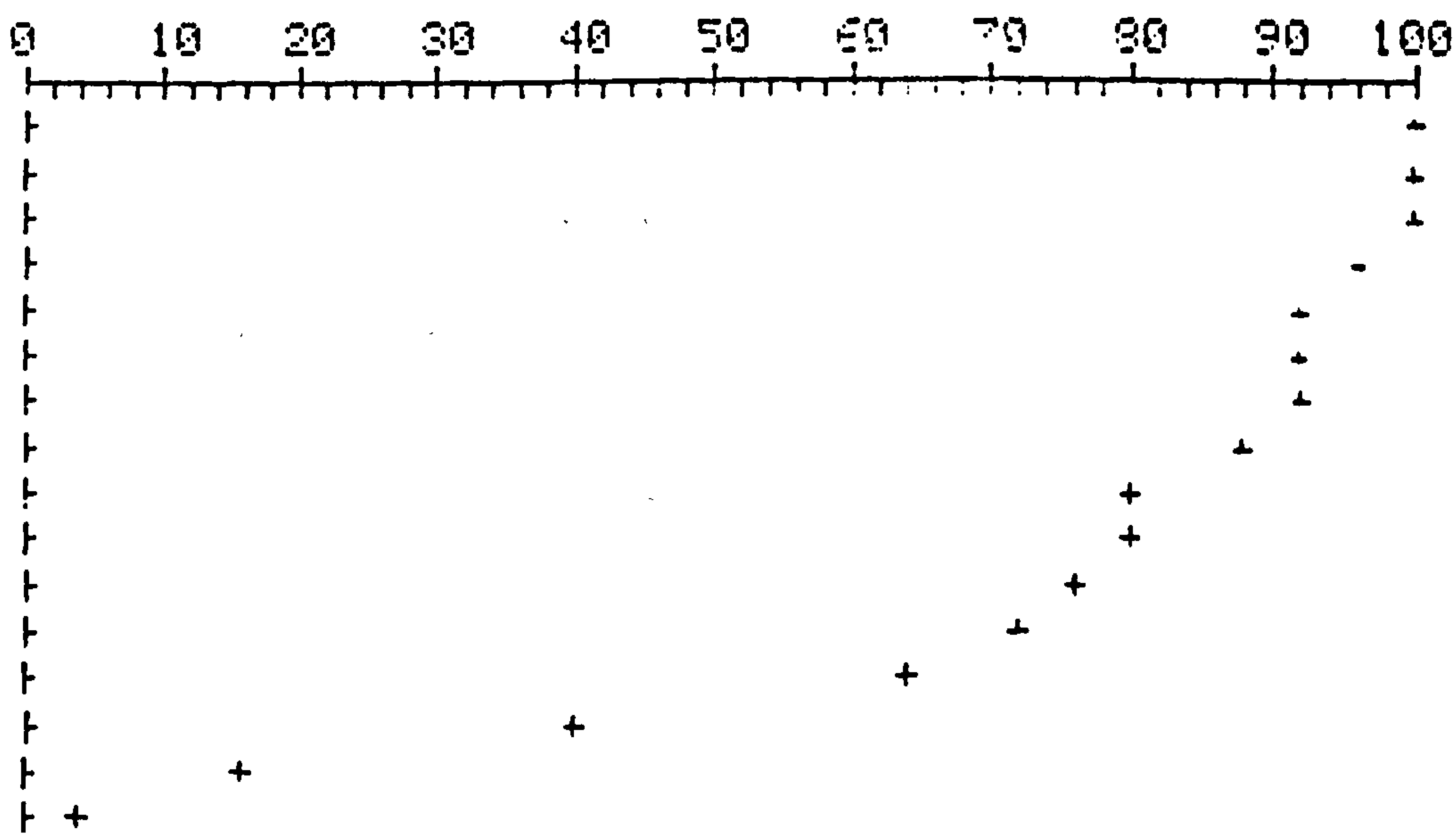


PHI	%
+ 9.00	.3
+ 8.00	.5
+ 7.00	2.9
+ 6.00	1.6
+ 5.00	1.1
+ 4.00	2.6
+ 3.00	4.1
+ 2.00	4.9
+ 1.00	2.7
+ .00	2.3
- 1.00	3.8
- 2.00	7.8
- 3.00	23.2
- 4.00	24.1
- 5.00	13.9
- 6.00	3.3

STATION NUMBER BATON 14 8

CUMULATIVE CURVE OF WHOLE SAMPLE

1 DIVISION EQUALS 2%



PHI	%
+ 9.00	99.3
+ 8.00	99.0
+ 7.00	98.4
+ 6.00	95.6
+ 5.00	93.9
+ 4.00	92.8
+ 3.00	90.1
+ 2.00	86.1
+ 1.00	81.1
+ .00	78.4
- 1.00	76.1
- 2.00	72.3
- 3.00	64.5
- 4.00	41.4
- 5.00	17.2
- 6.00	3.3

Grain Size Analysis

Station Number = sato 33/16

PHI SIZE	%	PHI SIZE	%
+ 9.00	91.070	+ 2.00	53.228
+ 8.00	88.168	+ 1.00	45.879
+ 7.00	84.436	+ .00	40.764
+ 6.00	78.630	- 1.00	36.990
+ 5.50	76.142	- 2.00	32.946
+ 5.00	71.166	- 3.00	27.258
+ 4.50	67.019	- 4.00	20.237
+ 4.00	63.287	- 5.00	12.829
+ 3.00	58.667	- 6.00	4.493

PERCENTILES		PERCENTILE STATISTICS			
5 %	- 5.93	TRASK MEDIAN	MD	+	1.560
16 %	- 4.57	INMAN MEAN	MO	+	1.176
25 %	- 3.32	FOLK MEAN	MZ	+	1.304
50 %	+ 1.56	INMAN SORTING	SO	+	5.748
75 %	+ 5.38	FOLK SORTING	SI	+	5.471
84 %	+ 6.92	FOLK KURTOSIS	KG	+	.806
95 %	+11.20	INMAN KURTOSIS	KO	+	.490
		INMAN SKEWNESS	A1	-	.066
MOMENT STATS		INMAN SKEWNESS	A2	+	.186
MEAN	+ .59	INMAN SKEWNESS	A2/A1	-	2.783
STD DEV	+ 4.50	FOLK SKEWNESS	SK1	+	.028
KURTOSIS	+ 1.55				
SKEWNESS	- .01				

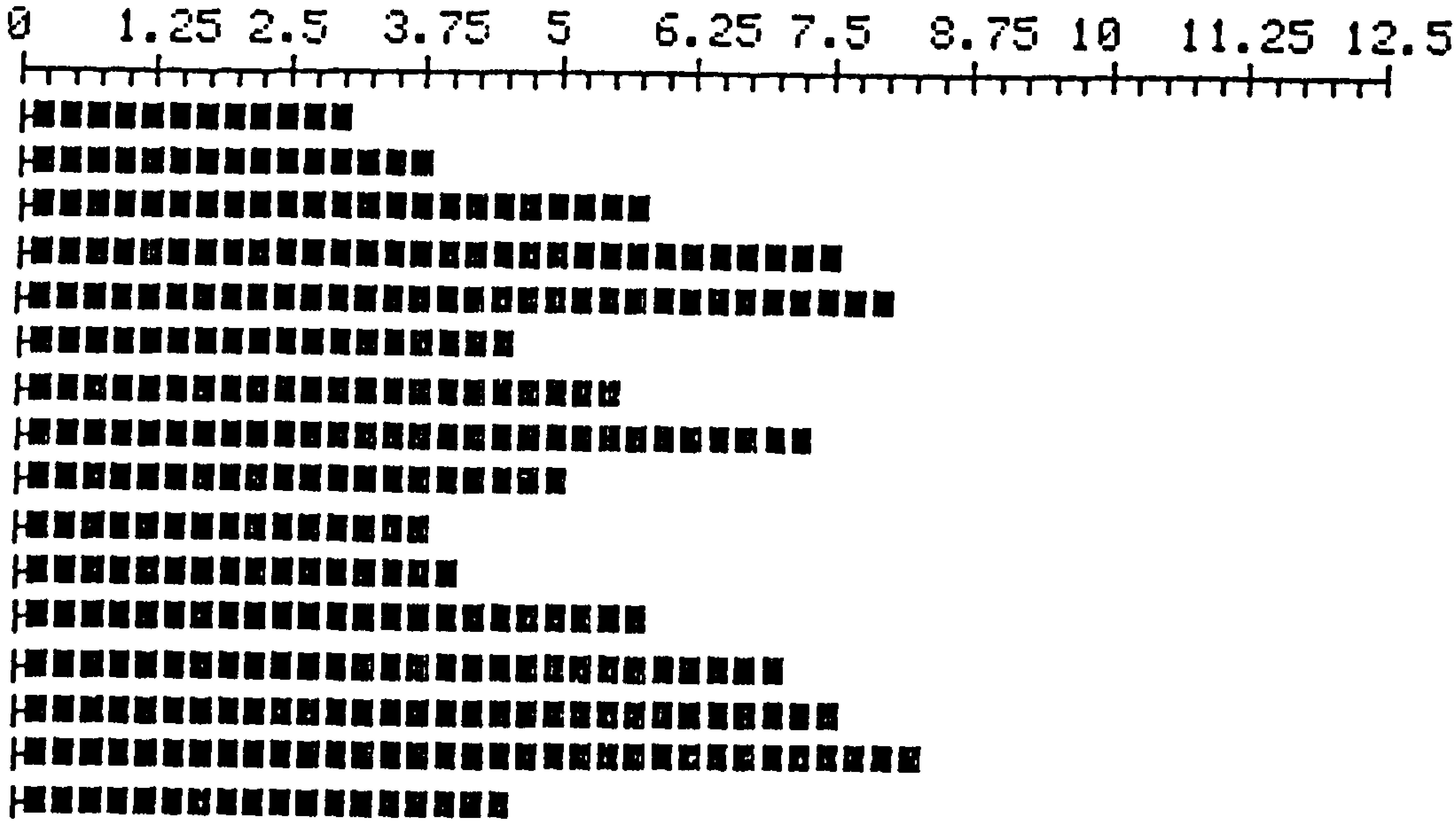
% MUD	< 4 PHI =	36.712
% SAND & GRAVEL	> 4 PHI =	63.287

STATION NUMBER GATC 33/16

HISTOGRAM OF WHOLE SAMPLE

1 DIVISION EQUALS .25%

PHI	%
+ 9.00	2.9
+ 8.00	3.7
+ 7.00	5.8
+ 6.00	7.5
+ 5.00	7.9
+ 4.00	4.6
+ 3.00	5.4
+ 2.00	7.3
+ 1.00	5.1
+ .00	3.8
- 1.00	4.0
- 2.00	5.7
- 3.00	7.0
- 4.00	7.4
- 5.00	8.3
- 6.00	4.5

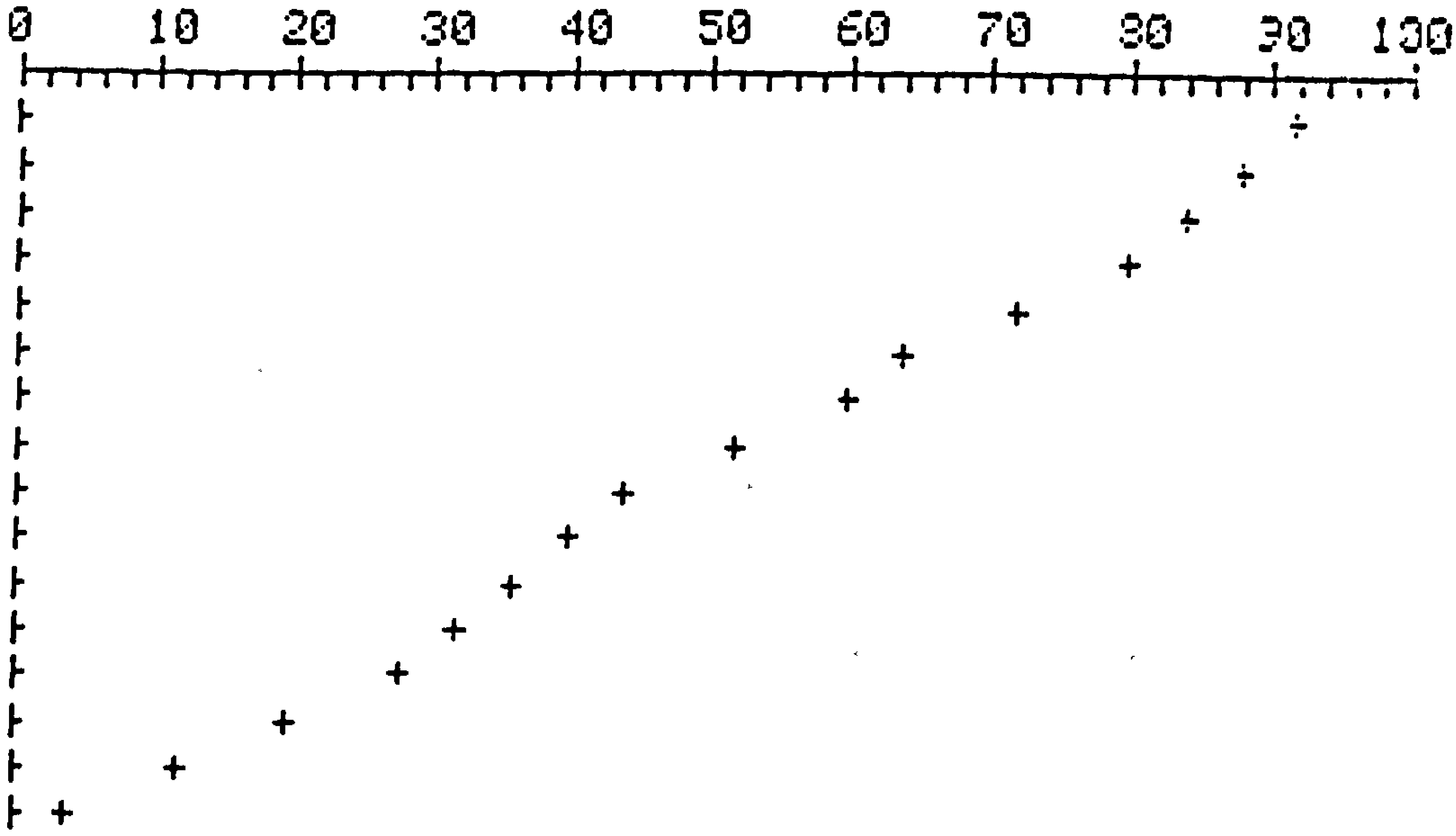


STATION NUMBER GATC 33/16

CUMULATIVE CURVE OF WHOLE SAMPLE

1 DIVISION EQUALS 2%

PHI	%
+ 9.00	91.1
+ 8.00	88.2
+ 7.00	84.4
+ 6.00	78.6
+ 5.00	71.2
+ 4.00	63.3
+ 3.00	58.7
+ 2.00	53.2
+ 1.00	45.9
+ .00	40.8
- 1.00	37.0
- 2.00	32.9
- 3.00	27.3
- 4.00	20.2
- 5.00	12.8
- 6.00	4.5



Grain Size Analysis

Station Number = a369/4

PHI SIZE	%	PHI SIZE	%
+ 9.00	98.782	+ 2.00	92.184
+ 8.00	98.683	+ 1.00	79.492
+ 7.00	97.992	+ .00	65.925
+ 6.00	97.152	- 1.00	60.205
+ 5.50	96.263	- 2.00	53.100
+ 5.00	96.214	- 3.00	40.718
+ 4.50	95.769	- 4.00	27.024
+ 4.00	95.572	- 5.00	4.894
+ 3.00	94.500		

PERCENTILES		PERCENTILE STATISTICS			
5 %	- 4.99	TRASK MEDIAN	MD	-	2.250
16 %	- 4.49	INMAN MEAN	MO	-	1.571
25 %	- 4.09	FOLK MEAN	MZ	-	1.797
50 %	- 2.25	INMAN SORTING	SO	+	2.926
75 %	+ .66	FOLK SORTING	SI	+	2.745
84 %	+ 1.35	FOLK KURTOSIS	KG	+	.728
95 %	+ 3.46	INMAN KURTOSIS	KO	+	.445
		INMAN SKEWNESS	A1	+	.231
MOMENT STATS		INMAN SKEWNESS	A2	+	.507
MEAN	- 1.65	INMAN SKEWNESS	A2/A1	+	2.188
STD DEV	+ 2.79	FOLK SKEWNESS	SK1	+	.291
KURTOSIS	+ 3.12				
SKEWNESS	- .73				

% MUD < 4 PHI = 4.427
% SAND & GRAVEL > 4 PHI = 95.572

STATION NUMBER A369/4

HISTOGRAM OF WHOLE SAMPLE

1 DIVISION EQUALS .5%

PHI	%
+ 9.00	.1
+ 8.00	.7
+ 7.00	.8
+ 6.00	.9
+ 5.00	.6
+ 4.00	1.1
+ 3.00	2.3
+ 2.00	12.7
+ 1.00	13.6
+ .00	5.7
- 1.00	7.1
- 2.00	12.4
- 3.00	13.7
- 4.00	22.1
- 5.00	4.9

STATION NUMBER A369/4

CUMULATIVE CURVE OF WHOLE SAMPLE

1 DIVISION EQUALS 2%

PHI	%
+ 9.00	98.8
+ 8.00	98.7
+ 7.00	98.0
+ 6.00	97.2
+ 5.00	96.2
+ 4.00	95.6
+ 3.00	94.5
+ 2.00	92.2
+ 1.00	79.5
+ .00	65.9
- 1.00	60.2
- 2.00	53.1
- 3.00	40.7
- 4.00	27.0
- 5.00	4.9

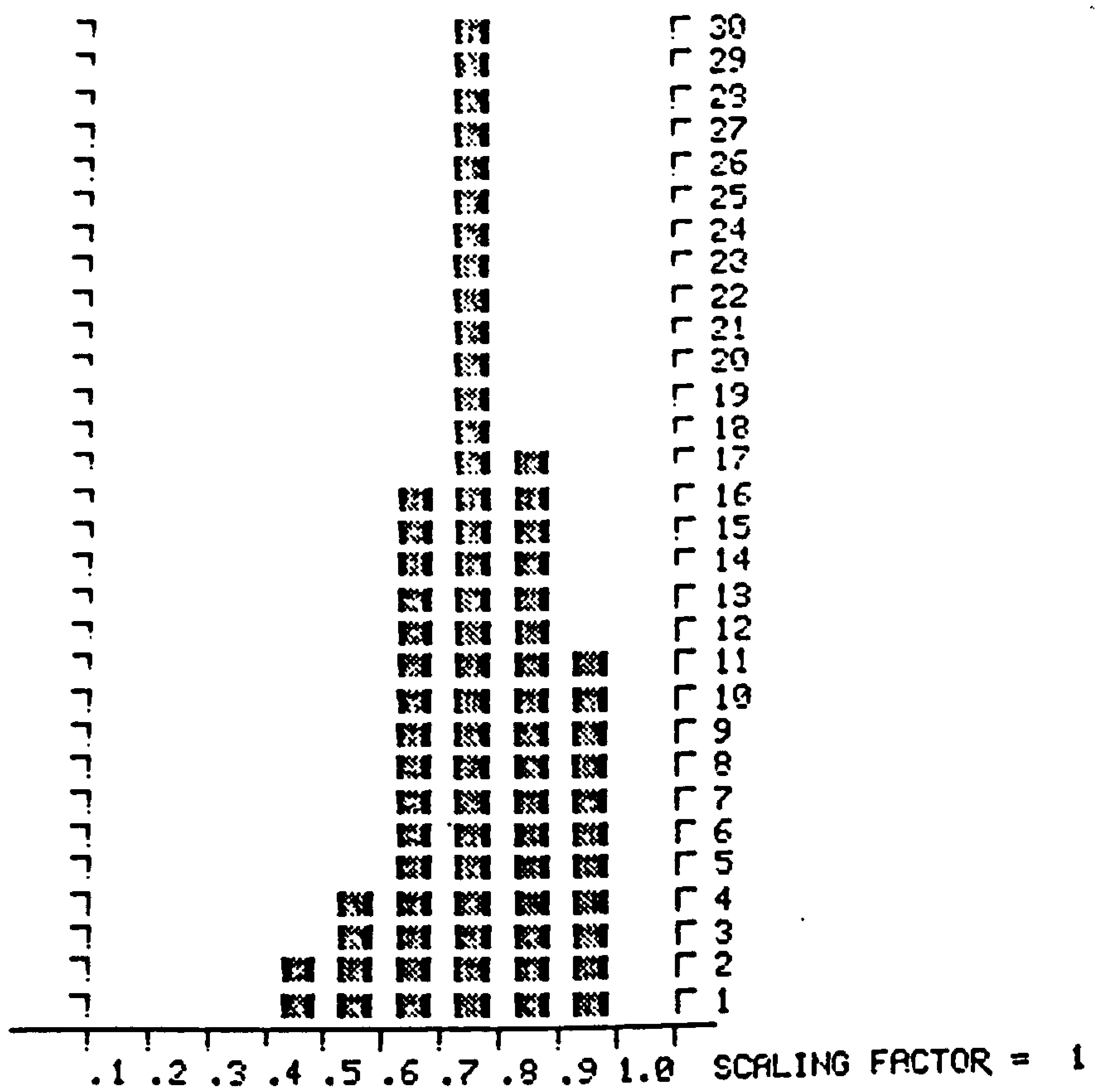
Sphericity Test.

Sample Number = cptp7 chporc

	LONG	MED	SHORT	SPHER	RATIO 1.	RATIO 2.	VIS SPHER	VIS ROUND	OBLATE PROLATE	% ELONG
1	5.55	4.55	3.40	.77	.61	.47	.70	.50	.49-	81.98
2	8.07	5.35	3.50	.66	.43	.60	.50	.30	2.31	66.29
3	5.05	5.05	2.10	.56	.42	.00	.30	.30	12.02-	100.00
4	3.66	2.50	2.10	.78	.57	.74	.30	.50	4.18	68.31
5	3.51	1.91	1.64	.74	.47	.86	.30	.10	7.70	54.42
6	5.72	4.61	3.85	.83	.67	.59	.70	.50	1.34	80.59
7	4.24	3.23	2.22	.71	.52	.50	.30	.30	.00	76.18
8	6.60	6.22	3.72	.70	.56	.13	.90	.50	6.56-	94.24
9	3.40	3.18	2.59	.85	.76	.27	.50	.50	3.02-	93.53
10	3.91	2.53	1.38	.58	.35	.55	.30	.30	1.42	64.71
11	4.75	2.47	2.24	.75	.47	.91	.30	.30	8.69	52.00
12	6.29	3.56	2.40	.64	.38	.70	.30	.30	5.24	56.60
13	3.95	3.63	1.97	.65	.50	.16	.90	.10	6.82-	91.90
14	4.19	3.11	2.21	.72	.53	.55	.70	.10	.95	74.22
15	3.51	1.77	1.71	.78	.49	.97	.70	.10	9.65	50.43
16	4.64	2.90	2.25	.72	.48	.73	.50	.30	4.74	62.50
17	4.41	3.95	3.10	.82	.70	.35	.90	.10	2.13-	89.57
18	3.79	2.75	2.30	.80	.61	.70	.50	.50	3.30	72.56
19	4.38	2.38	1.86	.69	.42	.79	.30	.10	6.83	54.34
20	3.81	2.37	1.86	.73	.49	.74	.30	.10	4.92	62.20
21.	3.55	2.49	2.20	.82	.62	.79	.50	.10	4.68	70.14
22	3.30	3.05	1.73	.67	.52	.16	.70	.10	6.49-	92.42
23	3.90	2.60	1.75	.67	.45	.60	.50	.30	2.23	66.67
24	5.18	4.37	3.58	.83	.69	.51	.70	.10	.14	84.36
25	7.78	4.85	1.80	.44	.23	.49	.70	.30	.43-	62.34
26	5.62	4.15	2.98	.72	.53	.56	.70	.10	1.13	73.84
27	4.19	3.11	2.05	.69	.49	.50	.50	.30	.00	74.22
28	5.00	2.85	1.46	.53	.29	.61	.50	.70	3.77	57.00
29	4.00	3.50	1.90	.64	.48	.24	.70	.30	5.47-	87.50
30	5.01	2.73	1.73	.60	.35	.70	.30	.50	5.79	54.49
31	4.90	3.00	2.38	.73	.49	.75	.50	.30	5.15	61.22
32	3.89	2.65	1.82	.68	.47	.60	.50	.30	2.14	68.12
33	5.87	3.52	1.90	.56	.32	.59	.50	.30	2.79	59.97
34	4.35	3.22	1.79	.61	.41	.44	.50	.50	1.46-	74.02

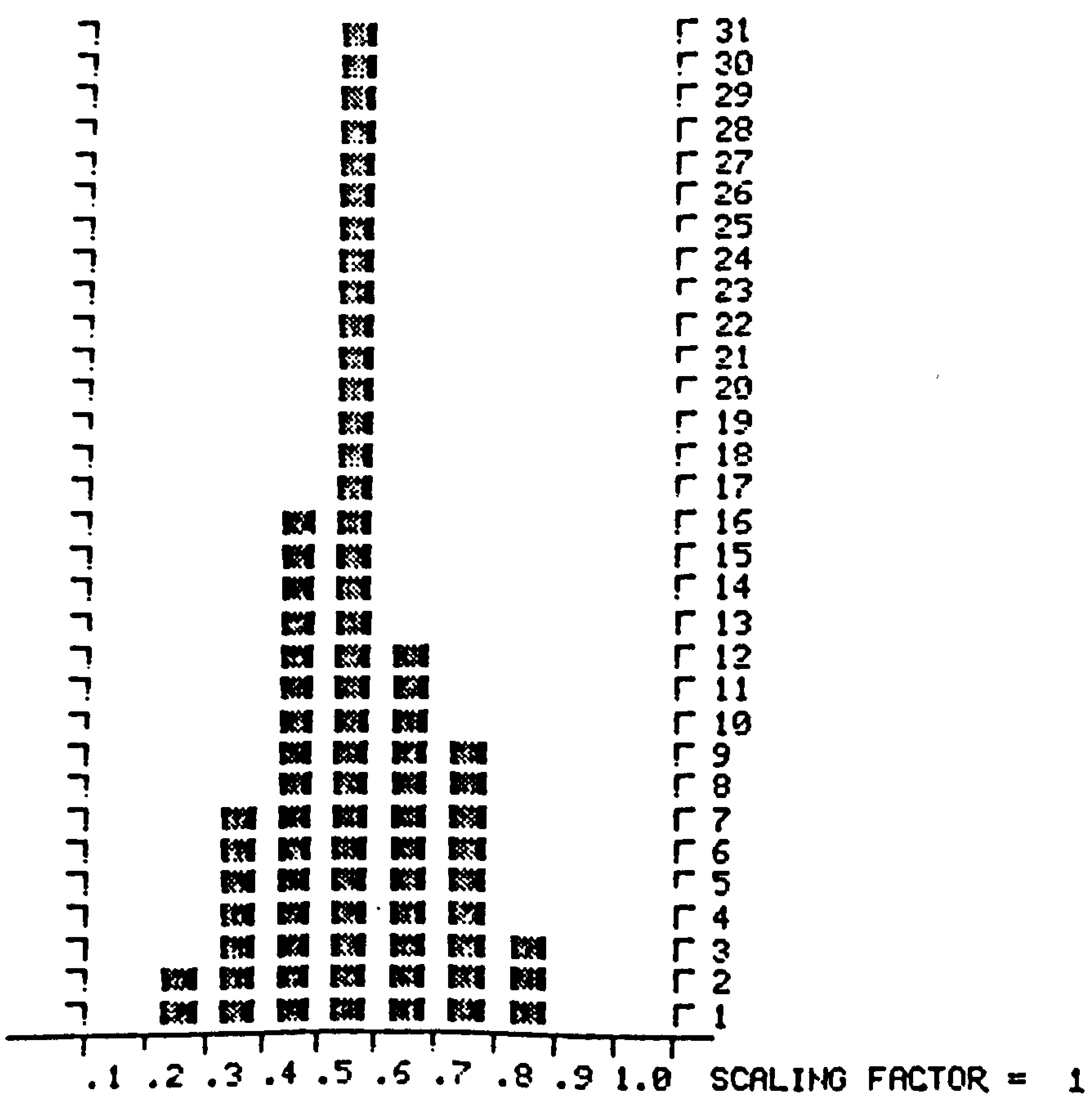
SAMPLE NUMBER. = CPTP7 CHPORC

HISTOGRAM OF SPHERICITY



SAMPLE NUMBER. = CPTP7 CHPORC

HISTOGRAM OF RATIO 1.



35	4.04	2.13	1.01	.49	.25	.61	.30	.20	4.40	53.96
36	4.05	1.73	1.30	.62	.32	.83	.30	.30	10.28	43.95
37	3.60	2.19	1.49	.65	.41	.67	.30	.10	4.14	60.88
38	3.90	2.58	1.60	.63	.41	.57	.30	.30	1.71	65.15
39	4.51	3.32	2.14	.67	.47	.50	.70	.30	.00	73.61
40	3.48	2.19	1.50	.67	.43	.65	.30	.50	3.48	62.93
41	5.10	1.75	1.32	.58	.26	.89	.30	.10	15.07	34.31
42	3.52	2.05	1.29	.61	.37	.66	.30	.10	4.37	58.24
43	4.25	4.03	1.60	.53	.38	.08	.90	.30	11.16-	94.82
44	4.89	4.35	2.39	.65	.49	.22	.90	.30	5.73-	88.96
45	3.55	2.38	1.30	.58	.37	.52	.30	.10	.55	67.04
46	3.43	2.79	1.65	.66	.48	.36	.70	.10	2.91-	81.34
47	2.93	2.70	1.40	.53	.48	.15	.50	.10	7.32-	92.15
48	3.96	2.39	1.69	.67	.43	.69	.50	.30	4.45	60.35
49	2.86	1.76	1.51	.77	.53	.91	.30	.10	5.87	61.54
50	3.45	2.55	2.26	.83	.66	.75	.70	.30	3.82	74.09
51	2.84	1.75	1.70	.83	.60	.96	.30	.10	7.68	61.52
52	3.26	2.75	2.37	.86	.73	.57	.70	.10	.96	84.36
53	2.21	2.00	1.63	.84	.74	.36	.50	.30	1.90-	90.50
54	3.30	2.10	1.30	.62	.39	.60	.30	.30	2.54	63.64
55	3.55	3.16	.71	.36	.20	.14	.50	.10	18.00-	89.01
56	2.80	2.45	.96	.51	.34	.19	.50	.30	9.04-	87.50
57	4.25	2.80	2.68	.85	.63	.92	.50	.10	6.66	55.88
58	2.00	1.96	.75	.53	.38	.03	.90	.30	12.37-	98.00
59	3.05	2.57	1.91	.77	.63	.42	.50	.30	1.23-	84.26
60	2.85	1.60	1.21	.68	.42	.76	.30	.10	6.12	56.14
61	2.76	1.70	1.13	.65	.41	.65	.30	.30	3.66	61.59
62	4.63	2.65	1.39	.54	.30	.61	.50	.10	3.66	57.24
63	4.11	2.97	1.89	.66	.46	.51	.50	.10	.22	72.26
64	3.51	2.21	.93	.48	.26	.50	.70	.30	.00	62.96
65	2.87	2.59	1.28	.61	.45	.23	.70	.50	6.05-	87.11
66	4.16	3.20	1.20	.48	.29	.32	.50	.30	6.24-	76.92
67	3.50	2.20	1.95	.79	.56	.84	.50	.10	6.10	62.86
68	2.18	1.61	1.31	.79	.60	.66	.30	.30	2.65	73.85
69	3.35	2.10	1.53	.69	.46	.69	.50	.10	4.16	62.69
70	2.50	1.41	.85	.59	.34	.66	.30	.10	4.71	56.40
71	2.90	2.13	1.36	.67	.47	.50	.50	.30	.00	73.45
72	3.00	1.75	1.64	.80	.55	.92	.30	.30	7.68	58.33
73	3.17	2.10	1.91	.82	.60	.85	.70	.10	5.81	66.25
74	3.05	1.82	1.00	.56	.33	.60	.50	.10	3.05	59.67
75	2.70	1.71	.93	.57	.34	.56	.30	.10	1.74	63.33
76	3.10	2.00	1.27	.64	.41	.60	.50	.30	2.44	64.52
77	3.05	1.93	1.14	.60	.37	.55	.50	.10	1.34	65.25
78	2.90	2.13	.55	.37	.19	.33	.50	.10	8.96-	73.45
79	2.55	1.71	1.05	.63	.41	.56	.50	.50	1.46	67.06
80	2.68	1.69	.91	.57	.34	.56	.30	.30	1.77	63.06
	MEAN.			MEAN	MEAN	MEAN		MEAN		MEAN.
	3.93			.67	.46	.56		.25		70.20
	STD. DEV.			STD. DEV.	STD. DEV.	STD. DEV.		STD. DEV.		STD. DEV.
	1.14			.11	.13	.23		.15		13.58

REL DEV
3.45

Photo 4.1: Meadow Farm, Bathampton : Lower "terrace"

Photo 4.2 :

Meadow Farm, Bathampton : TP19

Photo 4.3 :

Meadow Farm.
Bathampton.: TP15

Photo 4.4 : Twerton Linear Park, Bath : TP3

Photo 4.5 : Twerton Turnpike, 1968

PLATE 3

Photo 4.6 : Stidham Farm : Pit C

Photo 4.7 : Stidham Farm : overall stratigraphy of Pit A, West end, north face

PLATE 4

Photo 4.8 : Stidham Farm : Area 3, Pit C, the Lias Clay contact

Photo 4.9 : Stidham Farm : Pit A, Layer 9

PLATE 5

Photo 4.10 : Stidham Farm : Area 2, Pit C, Layer 8, Scale 0.5m

Photo 4.11 : Stidham Farm : Area 4, Pit C, Quartzitic sandstone boulder

PLATE 6

Photo 4.12 : Stidham Farm : North face, Oolitic limestone block

Photo 4.13 : Stidham Farm : Area 4, Pit C, channel fill

PLATE 7

Photo 4.14 :

Stidham Farm : Area 4, Pit C, detail of base of channel fill

Photo 4.15 : Stidham Farm : Pit A, Layer 3

PLATE 8

Photo 4.16 : Stidham Farm : Pit A, cryoturbation feature at 23m

Photo 4.17 : Stidham Farm : Area 3, Pit C, flame structures

PLATE 9

Photo 4.18 : Keynsham : TP9, alluvium over gravel top, Scale 0.5m

Photo 4.19 : Bitton : River Boyd, streambank exposure, Scale 0.3m

PLATE 10

Photo 4.20 :

Bitton : River Boyd, ox vertebra in alluvium above gravel

Photo 4.21 : Bitton : Holm Mead Lane Pit

PLATE 11

Photo 4.22 :

Bitton :
Holm Mead Lane,
TPB

Photo 4.23 : Brislington : TP2, Scale lm

PLATE 12

Photo 4.24 :

Wraxall : TP30

Photo 4.25 :

Gatcombe Farm : TP31

PLATE 13

Photo 4.26 : Chapel Pill Farm : East end of railway cutting, Scale 0.7m

Photo 4.27 :

Chapel Pill Farm : TP8

PLATE 14

Photo 4.28 : Chapel Pill Farm : Landslip section, detail of deposits

Photo 4.29 :

Ham Green :
Layer 4, Layer 3d,
Layer 3c,
Scale 0.5m

PLATE 15

Photo 4.30 : Ham Green : Layer 3b

PLATE 16

Photo 4.31 : Ham Green : Layer 4, Layer 3c, Layer 3a

Photo 4.32 :

A369 ditch :
58m, Scale 0.5m

PLATE 17

Photo 4.33 : A369 ditch : 37-40m, Scale 0.5m

Photo 4.34 : A369 ditch : sand lens at 42m, Scale 0.2m

PLATE 18

Photo 4.35 : A369 ditch : 14m, Scale 0.5m

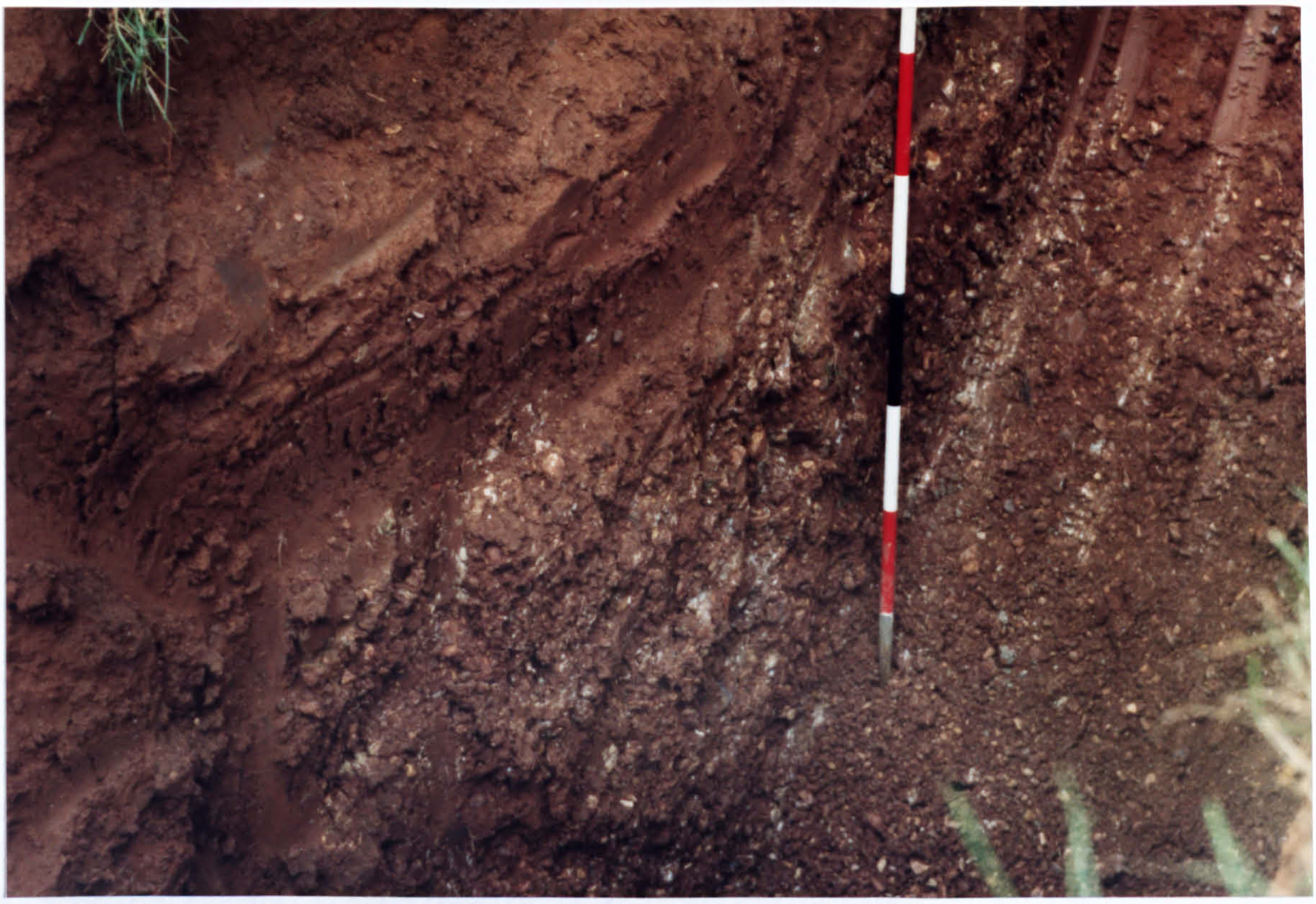


Photo 4.36 : Sheepway : TP12

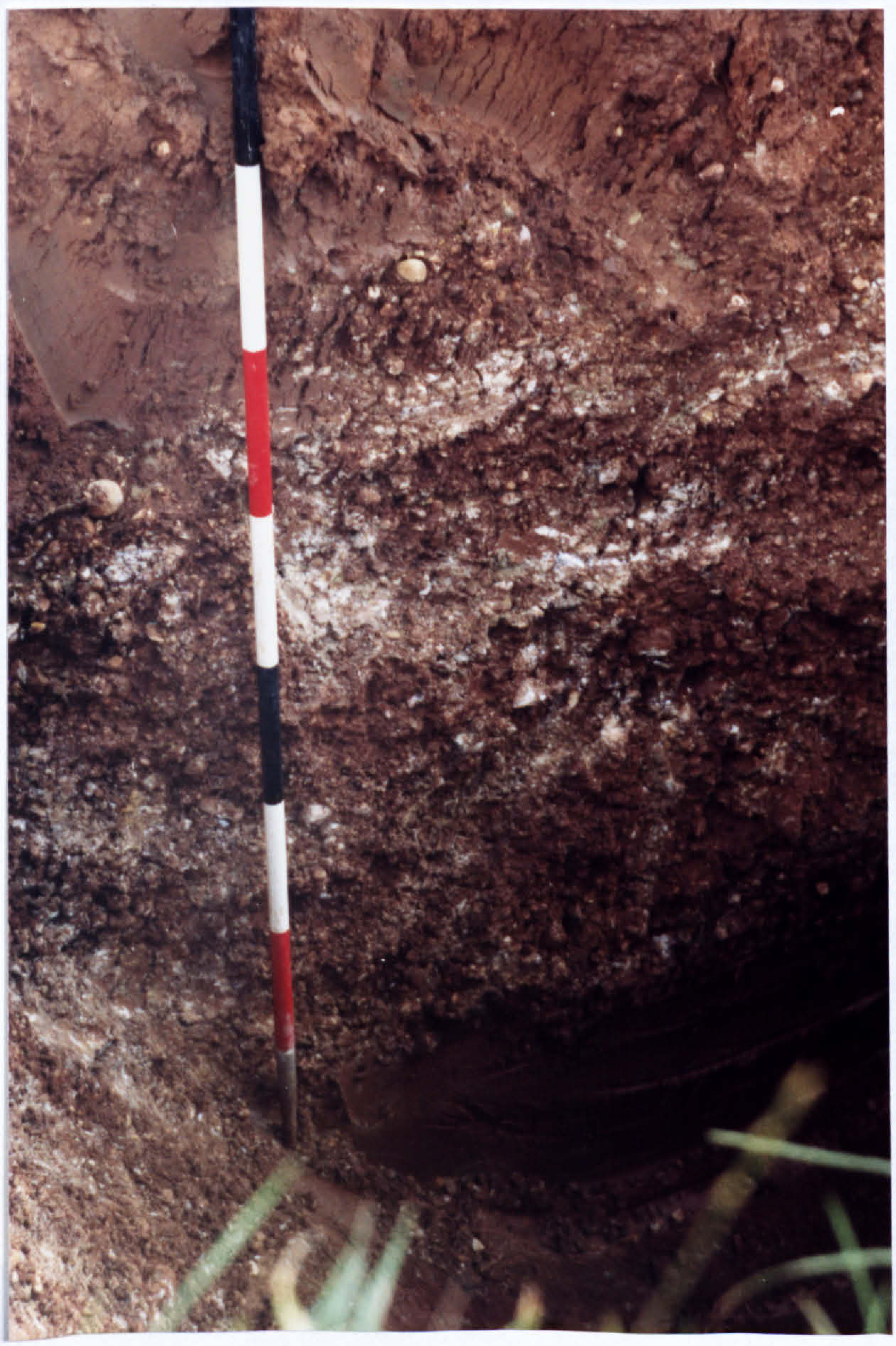


PLATE 19

Photo 4.37 :
Sheepway : TP13

Photo 4.38 : Sheepway : Exposure 1, whole section

PLATE 20

Photo 4.39 : Sheepway : Exposure 1, detail of pebbles, top of Layer 6